

SPAIN

OBSERVATIONAL ACTIVITIES

Continuous ozone, UV radiation and related atmospheric compounds monitoring and research is mainly conducted by the Meteorological State Agency of Spain (AEMET), former “Instituto Nacional de Meteorología” (INM), and the National Institute for Aerospace Technology (INTA). Departments of Atmospheric Physics and Meteorology of some Spanish universities do research on ozone and UV, most of them financed by the National R+D Plan of the Ministry of Education and Science. Some Regional Governments have implemented regional UV networks in the last three years.

Column measurements of ozone and other gases/variables relevant to ozone loss

Dobson spectrophotometer records

The longest total ozone record in Spain (since 1980) has been obtained with the Dobson spectrophotometer #120 installed at "El Arenosillo" station (Huelva) and operated by INTA. This instrument has been used in a number of intercomparisons at Davos and Hohenpeissenberg and is in operation at present. The latest calibration was held at El Arenosillo station in September 2007 against the European standard (Regional Dobson Calibration Center for Europe).

Brewer spectrophotometer national network

AEMET operates a national Brewer spectrophotometer network (Figure 1 and Table 1). The Brewer at the “El Arenosillo” station, financed by the Andalusian Regional Government, is managed by INTA. Total ozone and spectral UV are real-time monitored.



Figure 1: National UV broadband radiometer and spectrophotometer network

Figure 1: National UV broadband radiometer and spectrophotometer network

Table 1: National Brewer Spectrophotometer network

Station	Location	Instrument	Institution	Since	Last Calibration
A Coruña	43°N 8°W, 67 m	MK-IV #151	AEMET	Oct. 1998	Sep. 2007
Zaragoza	42°N 1°W, 258 m	MK-IV #166	AEMET	Nov. 1998 (#033) Nov. 1999 (#166)	Sep. 2007
Madrid	40°N 4°W, 680 m	MK-IV #070	AEMET	1988 (#033) May. 1992 (#070)	Sep. 2007
Madrid		MK-III #186	AEMET	May. 2007	Sep. 2007
Murcia	38°N 1°W, 69 m	MK-IV #117	AEMET	May. 1995	Sep. 2007
El Arenosillo	37°N 6°W, 30 m	MK-III #150	INTA	Jun. 1997	Sep. 2007
Izaña	28°N 16°W, 2373 m	MK-III #157	AEMET	May. 1992 (#033) Jul. 1998 (#157)	Aug. 2007
Izaña		MK-III #183	AEMET	Aug. 1995	Aug. 2007
Izaña		MK-III #185	AEMET	Mar. 2005	Aug. 2007
Santa Cruz Tenerife	28°N 16°W, 52 m	MK-II #033	AEMET	Oct. 2000	Aug. 2007

Data is collected on a daily basis through the AEMET local area network by a dedicated server located at the AEMET Data Processing Center. Data, once processed, is stored into the AEMET Massive Storage Devices (raw and processed files) and published in the AEMET web page.

The Network for the Detection of Atmospheric Composition Change (NDACC) Programme at the Izaña “supersite”

Since 2000/2001 the Izaña Observatory has participated in the NDACC (Network for the Detection of Atmospheric Composition Change) network (Former NDSC –Network for the Detection of Stratospheric Change-) as a complementary station in the following four programmes:

- Total ozone with a double Brewer spectrophotometer, managed by AEMET.
- ECC ozonesonde programme operated by AEMET.
- UV-VIS: An EVA instrument from INTA has been operating at Izaña Observatory since 1993 for measuring total column NO₂ and O₃. Two photodiode array spectrographs from INTA are running at Izaña since December 1998 and November 2001. One instrument routinely measures total columns of O₃, NO₂ and H₂O. Retrievals of Iodine monoxide (IO) and Formaldehyde (HCHO) have been attempted but their concentrations in the free troposphere are found to be below the instrument detection limit. The second UV spectrograph from INTA has expanded its capability to BrO. Bromine species are less regulated than chlorine species and their concentrations are believed to be increasing in the atmosphere due to Methyl Bromide (CH₃Br) and Halon emissions. Additionally, it has recently pointed out that a significant amount of bromine, possibly coming from halogenated VSLs (Very Short Lived Substances), is required to harmonize measurements with present state-of-the-art models. It is expected that the CFCs phasing-out will increase the future relative contribution of Bromine in the years to come. As secondary product Glyoxal (CHOCHO) is being retrieved but measurements are again below instrumental detection limits.
- Fourier Transform InfraRed (FTIR): From January 1999 to April 2005 a Bruker IFS 120M spectrometer was operated (Schneider et al., 2005b) at the Izaña Observatory by the Institut für Meteorologie und Klimaforschung (IMK) (Forschungszentrum Karlsruhe, Germany). Since January 2005 a Bruker IFS 125HR spectrometer is in operation. Zenith column amounts (ZCA) of trace gases such as O₃, H₂O, N₂O, CH₄, CO, OCS, HF, HNO₃, NO, NO₂, ClONO₂, HCl. Profiles of gases with narrow absorption lines such as O₃, NO, HCl and HF can be retrieved. For the atmospheric O₃ retrieval a combination of small and broad spectral windows between 780–1015 cm⁻¹ is analyzed.

The Antarctic UV-VIS network

In the framework of several projects funded by previous calls of the National R+D Plan of the Ministry of Education of Science, three UV-VIS spectrometers (EVA) designed and developed at INTA to measure column NO₂ and O₃ were installed at the permanent Argentinean bases of Belgrano (77° 52' S 34°37' W), Marambio (64° 14' S 56°37' W) and Ushuaia (54° 48' S 68°19' W), respectively, in 1994. The selected stations are scientifically of interest for Polar atmosphere studies since they cover areas in the stratosphere dynamically and chemically differentiated. The southernmost, which is Belgrano, is mostly located inside the vortex, Marambio is on the edge, and Ushuaia right outside the vortex. A new UV photodiode array spectrograph from INTA has been installed in October 2002 in Marambio (Antarctica) to retrieve zenithal column amounts of halogenated species, namely BrO, OCIO.

The main objective of this network is to provide both long term and near real-time observations of column O₃ and NO₂, in order to characterize the polar vortex and the O₃ destruction. Information related with this project, including instruments and stations, as well as the results of this network can be found at <http://www.spain.oracle-o3.org>

A long-term ozonesounding programme between INTA and DNA/IAA (Argentina) has been running at the Belgrano station (78°S, 35°W) since 1999. Ozonesondes have been regularly launched throughout the year providing an extremely valuable ozone vertically resolved dataset for seasonal characterization of the Antarctic ozone layer, detecting the magnitude of the depletion, periods of

occurrence, altitudes, etc. INTA has participated in previous years, and still participate nowadays, through the mentioned ozonesounding station in the Antarctic Match Experiment coordinated by the AWI (Alfred Wegener Institute, Germany). This experiment was carried out in connection with the European projects (QUOBI and Oracle-O3). Sondes were both European and nationally funded.

Profile measurements of ozone and other gases/variables relevant to ozone loss

Long-term programmes in Spain

The long-term ECC ozonesonde programme was initiated in November 1992 within the GAW programme at the AEMET's Izaña Observatory (Tenerife island). Ozonesoundings are launched from Santa Cruz de Tenerife station (36 m.a.s.l.), at a distance of 28 Km. from the Izaña Observatory, on a weekly basis and without any interruption since 1992. During intensive campaigns more than twenty sondes per month are launched. This is a NDACC programme. Quality control is assured by two simultaneous total column ozone comparisons from Brewer#33 (sea level) and Izaña Brewer triad (2373 m a.s.l.). Coincident ECC and FTIR ozone vertical profiles are compared in Tenerife since 2005.

Weekly ECC ozonesoundings have been carried out from 1992 to 2002 at the AEMET's Barajas (Madrid) radiosonde station. Early 2005 the ozone sounding programme was resumed and, since then, has continued without interruptions. Integrated total column ozone is validated against Brewer #070, which is located at about 25 km far from Barajas station.

INTA operates an ozonesounding facility at the El Arenosillo station with sporadic launches. Intensive campaigns, most of them funded by European projects, are frequently carried out at the later station.

A long-term ozonesounding programme between INTA and DNA/IAA (Argentina) is running at the Belgrano station (Argentina, 78°S, 35°W) since 1999. Since then and to date ozonesondes have been launched throughout a number of Spanish (MAR and "*Caracterización del vórtice Antártico y transporte meridional a partir de observaciones remotas de trazadores estratosféricos*") and European projects (QUOBI).

INTA and AEMET have participated in previous years, and participate nowadays, through the mentioned ozonesounding stations, at Keflavik, Madrid and Tenerife in the Match Experiment coordinated by the AWI (Alfred Wegener Institute, Germany). This experiment was carried out in connection with the European projects (EASOE, SESAME/OSDOC, THESEO/O3-LOSS, EUROSOLVE). Sondes were both European and nationally funded.

INTA's station at Keflavik (Iceland)

A long-term ozonesounding programme between INTA and IMO (Icelandic Meteorological Office) is running at the sub Arctic station of Keflavik (Iceland, 64°N, 22°W). Activities devoted to monitoring the ozone layer in the region of influence of the stratospheric polar vortex started in 1991 within the First Coordinated European Experiment for Ozone depletion Studies (EASOE). Since then and to date, ozonesondes have regularly been launched during winter through a number of European projects (SESAME, OSDOC, THESEO, QUOBI, SCOUT-O3) and will continue in the near future, at least until 2009.

Ushuaia GAW Station (Argentina)

A long-term ozonesonde programme has been initiated at the GAW Ushuaia station (Argentina) in April 2008 thanks to a joint collaboration of AEMET, INTA, the National Meteorological Service (SMN; Argentina) and the "Tierra del Fuego" Government (Argentina).

UV measurements

Broadband measurements

AEMET operates a national UVB (YES instrument) network since July 1999. Nowadays stations are described in Table 2.

Table 2: National UVB pyranometers network.

Station	Altitud	Latitud	Longitud	Yankee	Brewer
Almería	29	36° 51' N	02° 23' W	UVB	
Arenosillo (Huelva)	30	37° 06' N	06° 44' W	UVB	UV/O3
Badajoz	190	38° 53' N	07° 01' W	UVB	
Barcelona	35	41° 38' N	02° 12' E	UVB	
Cáceres	405	39° 28' N	06° 20' W	UVB	
Cádiz	15	36° 30' N	06° 16' W	UVB	
Ciudad Real	628	38° 59' N	03° 55' W	UVB	
Córdoba	91	37° 50' N	04° 51' W	UVB	
A Coruña	67	43° 22' N	08° 25' W	UVB	UV/O3
Granada	692	37° 08' N	03° 17' W	UVB	
Izaña	2373	28° 18' N	16° 30' W	UVB	UV/O3
León	916	42° 35' N	05° 39' W	UVB	
Madrid	680	40° 27' N	03° 43' W	UVB	UV/O3
Málaga	61	36° 43' N	04° 29' W	UVB	
Maspalomas (Gran Canaria)	25	27° 50' N	15° 57' W	UVB	
Murcia	69	38° 00' N	01° 10' W	UVB	UV/O3
Palma de Mallorca	10	39° 34' N	02° 45' E	UVB	
Roquetas (Observatorio Ebro)	44	40° 49' N	00° 29' E	UVB	
Salamanca	800	40° 57' N	05° 40' W	UVB	
Santander	79	43° 29' N	03° 48' W	UVB	
San Sebastian	259	43° 18' N	02° 02' W	UVB	
Santa Cruz de Tenerife	25	28° 16' N	16° 12' W	UVB	UV/O3
Valencia	57	39° 29' N	00° 28' W	UVB	
Valladolid	740	41° 39' N	04° 46' W	UVB	
Zaragoza	298	41° 40' N	01° 04' W	UVB	UV/O3

INTA is collaborating with the Institute of Aerospace Medicine from DLR on solar UV dosimetry by biological sensors (biofilms @). The collaboration covers the measurement campaigns at different locations in Spanish and German territory and the improvement of data analysis (image treatments, unattended exposure devices, etc).

Photosynthetic, UV-A and UV-B radiations are measured at tow sites in La Rioja (Logroño since 2001 and Valdezcaray since 2007) using broad-band meters (ELDONET type and Skye, respectively).

The Department of Physics of the University of Extremadura operates a regional network consisting in 6 radiometric stations (UV-S-E-T Kipp&Zonen UVER pyranometer). The stations are located at Badajoz, Cáceres, Plasencia, Orellana, Fuente de Cantos in Extremadura, and at the ski station La Covatilla in Southern Salamanca. The stations in Badajoz and Cáceres are operative since 2001 and Plasencia since 2002. The others have been recently installed in the last two years.

The Regional Government of Valencia, in collaboration with the University of Valencia, has deployed a 5-station (Prat de Cabanes, Aras de los Olmos, Valencia, Denia and Torrevieja) operational UVB regional network.

The Galician Regional Government (namely, Xunta de Galicia), through the University of Santiago de Compostela, has implemented a UV surface monitoring network in this Region. This network is made up by 5 Solar Light 501A radiometers located at different geographical sites, with diverse altitudes and environmental local conditions (Lourizan-Pontevedra, Ferrol, Pedro Murias, Alto do Rodicio and Ancares). The network is now managed by MeteoGalicia, the Galician Weather service.

Narrowband filter instruments

Three multi-channel narrow-band radiometers (NILU-UV6) were co-located by AEMET in the UV-VIS Antarctic stations in 1999, thanks to the scientific collaboration agreements signed by AEMET, INTA, DNA/IAA (Argentina) and the CADIC (Argentina). A fourth NILU-UV-6 is operated at the GAW Izaña Observatory. The NILU-UV6 instruments measure global radiation at five UV channels and PAR. A radiative transfer model is used to calculate the total ozone content, cloud transmittance and the biologically effective UV doses. Both complementary instruments are part of the Spanish Antarctic network that is now coordinated in the framework of some joint INTA-AEMET's projects ("MAR" REN2000-0245-C02-01; EGEO CGL2004-05419-C02-02ANT), financed both by the R+D National Programme. The Finnish Meteorological Institute (FMI) is in charge of the NILU radiometers' quality assurance system performing intercomparisons twice a year with a traveling reference NILU. The main objective of this network is to provide both long term and near real-time observations of column O₃ and UV radiation in order to characterize the polar vortex.

A NILU-UV-6 multichannel radiometer from the Department of Physics of the University of Extremadura is in operation at "El Arenosillo" Sounding Station (INTA) since December 2007.

In 2005 a multifilter radiometer (GUV 2511; Biospherical Instruments) was installed at Santiago de Compostela city. Nowadays research based on UV measurements with this instrument is carried out by the University of Santiago de Compostela, supported by MeteoGalicia.

Spectroradiometers

UV scans every 20 minutes have been obtained at the Izaña GAW Observatory from the Brewer spectrophotometers since May 1991.

A double spectroradiometer Bentham DM-150, installed in March 1999 at the GAW Izaña Observatory, provides global and diffused UV radiation scans every 15 minutes. This is one of the national UV reference instrument. Since June 2005 is also obtained direct sun UV scans. The Department of the Fundamental Physics of La Laguna University, in collaboration with INM, operates a double Bentham DM-150 spectroradiometer at the Izaña Observatory headquarters (SCO; sea level) in Tenerife. A comparison of the UV and visible spectra obtained from this spectroradiometer with those obtained at the Izaña Observatory (2400 m a.s.l.) have been used to study the connection between UV radiation and radiative properties of the atmospheric aerosols and clouds.

Episodic UV spectra are obtained by the Universities of Barcelona (Bentham DM-300), Valencia (Optronics and LICOR), Valladolid (LICOR) and la Laguna (Bentham and Optronics). Most of the measurements are used in investigations concerning the relationship between aerosol optical depth and spectral UV radiation.

Calibration activities

The WMO/GAW Regional Brewer Calibration Centre for RA-VI region (RBCC-E)

In November 2003 the WMO/GAW Regional Brewer Calibration Centre for Europe (WMO RA-VI region) (RBCC-E) was established at Izaña Observatory (IZO) at Tenerife (Canary Islands). The project is also intended to contribute to the GAW Programme in the RA-VI Region as a part of the closer co-operation between WMO and the European Commission being stated in the Memorandum of Understanding signed by WMO and EC in December 2003.

IZO is located in subtropical region (28°N) on the top of Izaña Mountain (2370 m.a.s.l.) with pristine skies and low ozone variability. This location allows routine absolute calibrations of the references in similar conditions to the Mauna Loa Observatory (MLO) site.

The RBCC-E reference is based on three double Mark-III Brewer spectroradiometers (the IZO triad): a Regional Primary Reference (B157), a Regional Secondary Reference (B185) and a Regional Travelling Reference (B183). The IZO triad is regularly sun calibrated by means of Langley method and by external lamps. The travelling reference ensures reference transference to the WMO-Region VI Brewer network.

Though B157, B183 and B185 are routinely calibrated by Langley plots method, these absolute calibrations are not used for definition of a new calibration scale. The MSC triad is respected as the official reference of the GAW Brewer international scale. The establishment of the IZO triad allows the implementation of a self-sufficient European Brewer calibration system that respects the world scale but works as independent GAW infrastructure. The IZO triad is linked to the world reference MSC triad with yearly calibrations towards the Canadian travelling reference B017. Systematic extraterrestrial constants (ETC) have been obtained by Langley method with B157 from 1998 to 2007. A comparison against ETCs transferred by travelling B017 shows an agreement within 1% in this period.

The function of RBCC-E also allows development and testing of new measurement techniques for the ground Brewer network like zenith, polarimetric, UV or aerosol optical depth measurements at IZO. A radiation laboratory and an electronic workshop are available at IZO for accurate fittings and indoors calibration and maintenance of the triad instruments.

Calibration of the national Brewer spectrophotometer network (AEMET)

The calibration of the spectrophotometers is scheduled as indicated below.

Table 3: Brewer's schedule Calibration

Brewer	Total ozone calibration (Travelling Standard #017 & RBCC-E triad)	Spectral UV calibration (NIST traceable)
#157,#185,#183,#033	Annually "in situ"	Against 1000w lamps
		Annually "in situ"
#151,#166,#117,#186,#070,#150	Bi-annually at El Arenosillo	Annually "in situ" and at El Arenosillo

The travelling standard Brewer #017 operated by IOS (International Ozone Service) company has provided ozone traceability to the world reference in Toronto for the Spanish Brewer instruments in September 2007, during the joint intercomparison of Brewer and Dobson organised by RBCC-E (AEMET) and RDCC-E at the INTA station "El Arenosillo" (Spain).

Spectral UV calibrations

AEMET has implemented a UV Quality Control/Quality Assurance (QC/QA) system for brewer spectrophotometer. QC consists of 50W lamp tests at each station performed every 2 weeks. Spectral UV absolute calibration is carried out every year using a portable 1000W lamp calibration system designed by Int'l Ozone Services Inc. (IOS, Canada). QA and UV calibration has been provided by PMOD with the European standard, the QASUME unit (PMOD/WRC), scheduled every 2 years (El Arenosillo, September 2005 and September 2007).

UV broadband radiometer network (AEMET) calibration

Concerning the broadband radiometer calibration, a procedure to calibrate the AEMET's UV broadband instruments (YES manufactured) is being implemented according to WMO recommendations. The spectral and angular responses are determined at the radiation laboratory at the AEMET's headquarters in Madrid. The final calibration for each instrument will be then determined taking into account the laboratory characterisation, the solar spectrum measured by a reference spectroradiometer BENTHAM DM-300 located on the roof of the AEMET headquarters, and the simulated solar spectra obtained running the libRadTran radiative transfer model for different total ozone and solar zenith angles.

A second broadband UV radiometer calibration laboratory is available, as a national facility, at El Arenosillo station (INTA). This laboratory fulfils the WMO requirements, and has been used by instruments of Regional networks of Spain.

AEMET and INTA have participated in two different broadband UV radiometer calibration/intercomparison campaigns were held at PMOD/WRC (Davos) and at El Arenosillo (Spain) in the 2006 and 2007 summers, organised by PMOD and INTA/UNEX/AEMET, respectively, as part of the objectives of the COST Action 726. The QUASUME European UV standard was the reference.

RESULTS FROM OBSERVATIONS AND ANALYSIS

A total ozone climatology and trend analysis has been performed by INM for each ozone station in Spain, as well as a comparison with overpass TOMS data.

Annual and diurnal UV index variations have been calculated for each capital of province.

Total ozone measurements from the five Brewer spectrophotometers located at the Iberian Peninsula have been compared with GOME (Global Ozone Monitoring Experiment) sensor by AEMET, in collaboration with the Remote Sensing Technology Institute of DLR, the German Aerospace Center for the period 1995-2004. Results show an excellent Brewer-GOME agreement. The effect of cloudiness, solar zenith angle, effective temperature and total ozone values in Brewer-GOME differences has been studied (Anton et al., 2008). Total column ozone from the Spanish Brewer network have been also compared with TOMS and ERA40 ECMWF reanalysis ozone fields during the same period.

The Group of Environmental Engineering and Bioprocesses of the University of Santiago de Compostela, have used spectral UV measurements to evaluate the influence of UV radiation and rain on fuel spills weathering in the Galician coast. The evaluation is carried out by comparison of the composition of fuel on a weathered slab with the composition of fuel located in a sheltered zone.

Total column ozone and vertical ozone profiles, using different techniques, are being inter-compared at the Izaña supersite. Results from DOAS vs Brewer, FTIR vs Brewer and FTIR vs ECC intercomparisons have been published in the last 3 years.

The SAUNA (Sodankylä Total Column Ozone Intercomparison) campaigns were held in February-April 2006 and 2007, confirms the ozone underestimation by Dobsons and single Brewers in high latitudes with high ozone concentrations, previously reported in TOMS Fairbanks campaign (2001). An empirical correction was proposed for single Brewers. AEMET-RBCCE contributes to the evaluation of the Brewer retrieval algorithm, concerning the use of different ozone absorption coefficients and the systematic errors caused by the assumption of stratospheric temperatures.

THEORY, MODELLING, AND OTHER RESEARCH

UVI forecasts are provided to the general public by AEMET since around six years ago. A new forecasting system based on Radtran Radiative Transfer Model and total ozone column ECMWF forecasts has been developed and put into operation along the last year 2007. The system runs daily up to D+5 and Maximum UVI forecasts are generated for about 60 cities in Spain. The system has been recently updated to spread the information to more than 8000 populated places in the country. The ECMWF model includes ozone mixing ratio as a 3D prognostic variable and is initialized every 12 hours with satellite data assimilation. UVI forecasts has been validated against the maximum UVI available observations (more than 20 stations) under clear sky conditions from May 2007 to Mid March 2008.

Departments of several universities are carrying out observations and studies regarding solar UV radiation and related atmospheric components. A summary of the activities performed by the Spanish universities is as follows:

- The Department of Optics and Applied Physics of Valladolid University is working on aerosol optical depth (AOD) characterization, including the UV range.
- The Department of Astronomy and Meteorology at Barcelona University has been taking sporadic measurements of UV and visible spectrum for the last nine years using a LI-COR 1800 spectroradiometer and now with a Bentham DM300 spectroradiometer. This group has also measured AOD. Work has also been done on simulation modeling using different radiative transfer codes.
- The Department of Thermodynamics at Valencia University is working on the aerosol observations and validating different radiative transfer codes.
- The Department of Applied Thermodynamics at Valencia Polytechnic University has been carrying out continuous measurements of UV with an Eppley radiometer since 1995.
- The Department of Fundamental and Experimental Physics at La Laguna University is working on aerosol characterization and its relationship with spectral UV radiation.
- The Atmospheric Physics Group at Granada University is working on solar radiation, remote sensing and aerosol characterization.
- The Department of Agriculture and Food at La Rioja University has been studying the effects of UV-B radiation on mountain aquatic bryophytes in their natural surroundings and has evaluated their use as bio-indicators. In addition, some studies on the effects of UV-B on grapevine have been conducted.

DISSEMINATION OF RESULTS

Data reporting

Daily mean ozone data from the Brewer spectrophotometer network is sent to the WMO Northern Hemisphere Daily Ozone Mapping Centre at the Aristotle University of Thessaloniki (Greece) and to the WOUDC, on a daily basis. Evaluated and refined data periodically submitted to the WOUDC database. Refined Brewer and ozonesonde data is submitted to NDACC and NILU databases every six months, and UV-VIS and FTIR data to NDACC and ENVISAT CAL/VAL databases, periodically. Data submission status is shown in Tables 4-7. Notice the existing agreement for periodical data transference from NDACC to WOUDC.

Table 4: Data available at WOUDC

Platform	Name	Category	Instrum.	S/N	Model	Min. Date	Max. Date
STN 308	Madrid (Barajas)	O ₃ sonde	ECC		6A	22-May-96	12-Mar-08
STN 308	Madrid (CR)	Total O ₃	Brewer	070	MKIV	01-Jan-92	29-Feb-08
STN 405	A Coruña	Total O ₃	Brewer	151	MKIV	01-Jan-04	29-Feb-08
STN 346	Murcia	Total O ₃	Brewer	117	MKIV	01-Apr-95	29-Feb-08
STN 411	Zaragoza	Total O ₃	Brewer	166	MKIV	01-Jan-04	29-Feb-08
STN 213	El Arenosillo	Total O ₃	Dobson	120	Beck	13-Jan-76	31-Dec-06
STN 213	El Arenosillo	Total O ₃	Brewer	150	MKIII	01-Jan-00	31-Dec-06
STN 300	Izaña (Tenerife)	Total O ₃	Brewer	157	MKIII	01-Jul-98	31-Jan-03
STN 300	Sta. Cruz Tenerife	Total O ₃	Brewer	033	MKII	26-May-91	09-Jun-95
STN 401	Sta. Cruz Tenerife	O ₃ sonde	ECC		6A	05-Jan-99	28-May-03

Table 5: Data available at NDACC (<ftp://ftp.cpc.ncep.noaa.gov/ndacc/>)

Programme	Station	Institution	Min. Date	Max. Date
Total Ozone (Brewer)	Izaña	AEMET	Jul. 1991	Apr. 2006
Ozonesonde (ECC)	Sta.Cruz,Tenerife	AEMET	Jan.1995	Apr. 2006
UV-VIS/DOAS	Izaña	INTA	Jan. 2000	Apr. 2006
FTIR	Izaña	IMK	Mar. 1999	Oct. 2005

Table 6: Data available at ENVISAT CAL/VAL

Station	Institution	Min. Date	Max. Date
Izaña (UV-VIS)	INTA-AEMET	Jan. 2000	Dec. 2007
Izaña (FTIR)	IMK-AEMET	Feb. 1999	Dec. 2007

Table 7: Data available at NILU

O ₃ Station	Institution	Min. Date	Max. date
Belgrano II	INTA	Mar. 1999	Dec. 2007
Keflavik	INTA	Nov. 1991	Dec. 2007

Ozone profiles (INTA/DNA) data over Antarctica have been sent to NILU database in the framework of QUOBI, ORACLE-O3 projects and Match Campaigns.

NO₂ data over Marambio and Belgrano station are sent to NILU-European database in the framework of ESA CAL-VAL.

NO₂ data over Marambio, Belgrano and Ushuaia stations are sent to GEOMON database in the framework of GEOMON project.

The "Iberonesia" web-based data managing interface (www.iberonesia.net) provides near-real time ozone and UV information of the Brewer spectrophotometer network. Three Brewers from Portugal and two from Casablanca (Morocco) have been incorporated to this network. The information is stored and validated automatically.

Data (CIE, UVI, UVA, UVB, UVA/UVB, PAR, Ozone and CLT) from the NILU Antarctic can be downloaded from www.polarvortex.org.

Ozone soundings from Keflavik/Iceland are posted in real time in the joined IMO-INTA. Web page: <http://grenjandi.vedur.is:8080/ozone/>.

Ozone profiles data over Antarctica are sent to the WMO in almost real time as contribution to the reports on the evolution of the Ozone hole
www.wmo.ch/pages/prog/arep/gaw/ozone/index.html#AntBull

Information of the INTA/AEMET Antarctic project for the three stations are disseminated through www.spain.oracle-o3.org.

A Summer Course on "Ultraviolet radiation: effects on human health and environment" was organized at the La Rioja University, Alfaro (La Rioja), 11-13 July 2007.

The webpage www.unirioja.es/ecophys/ shows the results obtained by the Group of "Ecophysiology, Climatic Change and Environment" at the La Rioja University related to the effects of UV on ecosystems.

Information to the public

Observed total ozone column data from Brewer and observed UVI data from broadband radiometers are disseminated through the AEMET web page (1 day delay) in the following address: www.aemet.es/es/eltiempo/observacion/radiacionuv?opc1=estac&datos=graf

UVI forecasts are disseminated through the AEMET web page up to D+5 in the capital cities, autonomous cities and island capitals, and D+3 in the rest of the places. The information is available at www.aemet.es/es/eltiempo/prediccion/radiacionuv.

UVI forecasting is published by the Valencia Regional Government for five sites of this Region at www.cth.gva.es/cidam/emedio/uv/.

The AIRE research group (Department of Physics of the University of Extremadura) provides nearly real time information about the UV index (UVI) measured and the forecasted maximum daily value for Badajoz, Cáceres, Plasencia, Orellana, Fuente de Cantos in Extremadura, and at the ski station La Covatilla in Southern Salamanca. This information is on-line available at <http://aire.unex.es/uvj>.

The University of Santiago de Compostela (supported by MeteGalicia) provides +48h UV Index forecasting for cloudless conditions in 14 locations of Galicia. Clear sky UVI forecasting is corrected manually by a meteorologist using the forecasted cloud cover, following the guidelines provided by the COST 713 Action. This task is operative from April to October, as the period when UVI levels are higher and more dangerous for the public (www.siam-cma.org/meteorologia/uv/prediccionuv.htm).

The Servei Meteorològic de Catalunya provides information and predictions of UVI for Catalunya at www.meteocat.com/marcs/marc_prediccio.html.

EuskalMet, the Meteorological Agency of the Basque Country (www.euskalmet.euskadi.net/s07-5853x/es/meteorologia/meteodat/uvi.apl?t=3&e=5) provides UVI forecasting for eight locations in the Region.

Ozone data over Antarctica are sent to the WMO in almost real time as contribution to the reports on the evolution of the Ozone hole (www.polarvortex.org).

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PROJECTS AND COLLABORATION

International Polar Year

INTA is involved in ORACLE-O3 (Ozone layer and UV radiation in a changing climate evaluated during IPY) project. This project is a cluster which brings together the tasks of 16 expressions of interest (EOI) submitted to IPY Joint Committee. It deals with experimental and modelling research on the ozone layer, UV radiation and the effects of personal UV exposure during the IPY. During the project, INTA ground-based observations are being performed at Ushuaia, Marambio and Belgrano stations by means of UV-VIS spectrometers, to measure the seasonal and long-term variability of ozone, NO₂, and other ozone-related trace gases. Radiosonde and ozonesonde in Keflavik and Belgrano provide measurements of wind and temperatures in the troposphere and stratosphere. The project implies accurate quantification of polar ozone losses in both hemispheres achieved with concerted international campaigns during which hundreds of ozonesondes are launched in real-time coordination from station networks in the Arctic and Antarctic. Antarctic Campaign was performed in June-October, 2007 and Arctic campaign in December, 2007–March 2008.

Within the IPY, AEMET-RBCCE has trained four persons of the Antarctic Institute of Uruguay (AIU) in Brewer operation, maintenance and data evaluation at the Izaña Observatory. The Brewer#155, from AIU has been repaired and calibrated by the RBCCE at Izaña. This instrument was installed, with the participation of AEMET-RBCCE, at the Artigas Antarctic Base (62° S y 59° W; King George, South Shetland Islands) on December 11, 2007. This cooperation project has been financed by the Canary Islands Government.

European Projects

- **SCOUT-O3** (Stratospheric-Climatic Links with Emphasis on the UTLS); SCOUT-O3's aim is to provide predictions about the evolution of the coupled chemistry/climate system, with emphasis on ozone change in the lower stratosphere and the associated UV and climate impact, to provide vital information for society and policy use. It is a 54 partners international integrated project funded by EU, among them, INTA participates in collaboration with AEMET by observations and interpretation of ozone in the UTLS region by Ground-based and ozonesonde data.
- **GEOMON** (Global Earth Observation and Monitoring of the Atmosphere) in a [European project](#) contributing to [GEOSS](#). Its mission is to build an integrated pan-European atmospheric observing system of greenhouse gases, reactive gases, aerosols, and stratospheric ozone. Ground-based and air-borne data are sustained and analyzed, complementary with satellite observations, in order to quantify and understand the ongoing changes of the atmospheric composition. INTA participates by routine measurements, quality control and data storage in general data base of stratospheric ozone related gases.
- **Action COST-723**: Spain has endorsed the EU Action COST 723 ("The Role of the Upper Troposphere and Lower Stratosphere in Global Change"; www.cost723.org/).
- **Action COST-726**: Spain has endorsed the EU Action "Long term changes and climatology of UV radiation over Europe": <http://i115srv.vu-wien.ac.at/uv/COST726/Cost726.htm>

Projects funded by the National R+D Plan of the Ministry of Education and Science

- **MARACA** (Medida de componentes Atmosféricos en la Región Antártica y Ártica, CGL2004- 05419-C02-01, 2004-2007)
- **CEORACLE-O3** (Contribution from Spain to "Oracle-O3", POL2006-00382, 2007-2009) in the framework of the International Polar Year.
- **TROMPETA** ("TROPical Monitoring Phase in the Atmosphere"), It is an INTA project with strong collaboration by AEMET. Reference CGL2004-03669/CLI, financed by the Diversity,

Earth Sciences and Global Change R+D National Programme. Its goal is to understand radiative transfer in the atmosphere during strong Saharan dust events and its impact on ozone measurements from nadir-looking satellites. Izaña supersite facility is used in this project.

Satellite validation exercises

Pole to pole extensive validation of the SCIAMACHY instrument on board of the European ENVISAT platform has been performed through the ESA contracts TASTE and TASTE-II. INTA has participated via IASB/BIRA Belgian Institute on O₃ and NO₂ total column species on years 2005-2007 by its ground-based instrumentation located at Izaña (Subtropical), Ushuaia, Marambio and Belgrano (Antarctica). Further validation, on a climatological perspective, from Izaña observatory has included GOME data as well and other ESA instruments (GOME, SCIAMACHY, GOMOS, MIPAS).

The European Brewer reference (RBCC-E at Izaña Observatory) has participated in SAUNA (Sodankylä Total Column Ozone Intercomparison) campaigns was held in 2006 and 2007 with the European Brewer reference. Satellite and ground-based measurements have been compared under a greater variety of ozone column amounts and profile shapes. The objective of SAUNA is to assess the comparative performance of the ground-based instruments, space-based instruments and algorithms which measure total column ozone at large solar zenith angles and high total column ozone amounts. See details at <http://fmiarc.fmi.fi/SAUNA/>.

Validation of ESA/GOME, SCIAMACHY/ENVISAT, NASA/KNMI and OMI/AURA, of more than a dozen of atmospheric components, using advanced scientific instrumentation, has been performed during 2005-2008 by the FTIR, managed by IMK-ASF Forschungszentrum Karlsruhe, at Izaña supersite.

AEMET, the University of Extremadura (UNEX, Spain) and DLR are collaborating on the validation of GOME2 ozone (DLR) over Spain using the AEMET Brewer network and ozonesonde data over Madrid.

National intercomparison campaigns

The INTA, AEMET and the AIRE research group (University of Extremadura) have organized, in collaboration with the World Radiation Center (PMOD/WRC), and partially supported by the COST-726 Action, the national Broadband Calibration Campaign held at "El Arenosillo" (Huelva, Spain) from August 15 to September 21, 2007. Twenty two (22) UV broadband instruments, from 13 different institutions, took part in the intercomparison.

International intercomparison campaigns

- An intercomparison campaign of seven UV spectroradiometers of different types took place at the high altitude site of Izaña, Canary Islands, in June 2005. The campaign was focused primarily on spectral measurements of direct solar irradiance. Among the objectives was to improve the quality of direct solar irradiance spectral measurements, through instrumental modifications and standardization of calibration techniques, as well as to assess the significance of the differences in the field of view of the spectroradiometers with respect to aerosols and to solar zenith angle.
- In September 2005 and September 2007 were held the first and the second, respectively, Brewer intercomparison campaigns at El Arenosillo station (INTA). The scientific coordination and organization corresponded to the GAW Regional Brewer Calibration Center for Europe (RBCC-E). During the second Brewer intercomparison in 2007 a Dobson intercomparison campaign was organized by the Regional Dobson Calibration Centre-Europe (WMO-RDCC-RA-VI) Meteorological Observatory Hohenpeissenberg (Germany). During the first days both calibration campaigns performed in parallel, while the last days were used for a Dobson/Brewer comparison. In the two Brewer intercomparisons two Brewers from Morocco were fitted and calibrated.

PSC detection

Two campaigns for MPL-4 lidar validation on PSC detection has been carried out during 2007 for testing the capability of highly modulated unattended "eye safe" lidars for ozone depletion studies:

- Ny-Alesund (Spitzbergen, Norway). In collaboration with the Alfred-Wegener Institute (AWI) measurements were performed at AWIPEV French-German Research Base, Arctic Koldewey Station (1/12-2/9, 2007).
- Sodankyla (Finland). In collaboration with the Finnish Meteorological Institute (FMI). Measurements were carried-out in the Arctic Research Center (ARC) within the frame of the international project SAUNA-2 (Sodankyla totAl colUmn ozoNe intercompArison 2), (2/11- 3/31, 2007).

Other activities

INTA, UNEX and AEMET keep close contact concerning the calibration procedures for broadband UV radiometers.

FUTURE PLANS

The Andalusian Network of UVI measurements will be set up in 2008. Eight (8) stations will cover representative locations of social interest within the Andalusian territory. The network will be maintained and calibrated by INTA and extended information will be supplied to the public via web site and street panels.

INTA will install a MPL-Net Lidar in Belgrano Antarctic station, for detecting Polar Stratospheric Clouds, in 2008. The lidar is being tested at INTA Headquarters in Madrid.

INTA will ask to incorporate to NDACC the Antarctic spectrometers and Belgrano ozonesoundings in 2008. The quality of the spectral data has been verified by performing daily intercomparison measurements between a similar Antarctic spectrometer and PDA installed at Izaña station.

Improvement of polar observing stations (Belgrano, 2009) is foreseen as one of the most important INTA's IPY objectives by the following actions:

- A highly modulated eye-safe almost unattended Micro lidar will be deployed at Belgrano for long term monitoring of Polar Stratospheric Clouds (PSC).
- Two spectrographs devoted to measure OCIO and BrO and an improved third one to measure NO₂, O₃, O₄, and colour index will be deployed. First instrument has an off-axis capability to provide also tropospheric abundances of BrO.

AEMET will ask to incorporate the spectral UV programme at Izaña Observatory into the NDACC. A new UV-VIS CCD spectrometer has been purchased to complement the spectral UV range provided by the Brewer triad.

A close "twinning" partnership between the AEMET's Izaña GAW station and the Tamanrasset-Assekrem GAW station (Algeria) was initiated in September 2006. This collaboration is currently being reinforced thanks to the "Agencia Española de Cooperación Internacional" (AECI; Azahar programme) which has financed a double Brewer spectrophotometer for the Tamanrasset station and a multi-channel moderate band-width radiometer for the Assekrem station, which will be deployed in 2008-2009. This new equipment in a strategic site in the middle of the Sahara will fill an important gap in the GAW observational capacity, and will constitute a unique ozone, UV and aerosol ground-truthing facility for space-based sensors.

AEMET is implementing 17025:2005 standard procedures in the National Radiometric Laboratory installed in 2007 at the AEMET headquarters in Madrid (Spain). In near future, TOC and ozone vertical observations will be provided in near real-time to ECMWF for the validation of the new ozone forecast fields in the framework of the GEMS Project.

The time series of AEMET's Brewer UV irradiance data will be re-evaluated taking into account the calibration results against the European standard and the cosine error. Historic data from broadband UV radiometers will be also re-evaluated according to WMO recommendations.

The University of La Rioja will perform the project entitled "Prospective and Retrospective Bioindication of UV Radiation using Aquatic Bryophytes".

NEEDS AND RECOMMENDATIONS

Further developments are required in cloud forecasting. Accurate knowledge about effects of clouds on UV is needed. These aspects are essential to achieve a realistic UVI prediction in operational systems.

Near real-time data exchange within WOUDC, NDACC and other (NILU, CAL-VAL) databases should be implemented as soon as possible. This would facilitate the ozone and UV validation exercises of numerous existing models.

Monitoring systems should be expanded to Upper Troposphere-Lower Stratosphere (UTLS) region.

The adoption of common methodologies for the calibration of UV radiometers, and the organisation of periodic laboratory intercomparisons is needed and highly recommended in order to have reliable and inter-comparable UV radiation observations.
