

SPAIN

1. Ongoing activities

Continuous ozone, UV radiation and related atmospheric compounds monitoring and research is mainly conducted by the Instituto Nacional de Meteorología (INM) and the Instituto Nacional de Técnica Aeroespacial (INTA). The Departments of Physics and Meteorology of several Spanish universities do research on ozone and UV. Most of the national actions are financed by the National R+D Plan of the Ministry of Science and Technology.

1.1 Monitoring and QC/QA systems

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 is in operation at present. The latest calibration was held at Arosa Dobson intercomparisons in August 1999. Data are submitted to the World Ozone and Ultraviolet Radiation Data Centre (WOUDC-AES, Canada) every 6 months.

1.1.1. Brewer spectrophotometer national network

INM operates a national Brewer spectrophotometer network (Figure 1 and Table 1), partially financed by the National R+D Plan of the Ministry of Science and Technology. The Brewer at the "El Arenosillo" station, financed by the Andalusian Regional Government, is managed by INTA. This network provides total ozone and spectral UV that is real-time monitored through the INM's intranet. The information is stored and validated in a centralized database.

Total ozone daily means are submitted daily to the WMO Northern Hemisphere Daily Ozone Mapping Centre run by the Laboratory of Atmospheric Physics at the Aristotle University of Thessaloniki (Greece) and to the WOUDC.



Figure 1; National UV broadband radiometer and spectrophotometer network

Evaluated and refined total ozone data from Madrid, Murcia and Izaña stations are periodically submitted to the WOUDC database.

The Brewers (#033 and #157) at the Izaña Observatory have been intercompared with the international traveling reference Brewer#17 every year since 1991. Other Brewers of the network are intercompared and calibrated every two years. Last two intercomparisons were held at the El Arenosillo station in September 1999 and September 2001.

Since November 1999 the Brewer network has performed a common measurement schedule (ozone and spectral UV) on a daily basis. This information is stored in the centralized INM database. Spectral UV Quality Control (QC) consists of 50W lamp tests at each station performed every 2 weeks. Spectral UV Quality Assurance (QA) is carried out every year using a portable 1000W lamp calibration system designed by Int'l Ozone Services Inc. (IOS, Canada). Primary standard lamps (NIST traceable) are located at the optical lab of the Izaña Observatory. Before and after the national calibration trip 1000W secondary standard lamps are calibrated against the primary ones.

Station	Location	Instrument	Institution	Since	Last calibration
A Coruña	43°N 8°W	Brewer MK-IV #151	INM	Oct 1998	September 2001
Zaragoza	42°N 1°W	Brewer MK-IV #166	INM	Nov 1998 (#033) Nov 1999 (#166)	September 2001
Madrid	40°N 4°W	Brewer MK-IV #70	INM	1988 (#033) May 1992 (#070)	September 2001
Murcia	38°N 1°W	Brewer MK-IV #117	INM	May 1995	September 2001
El Arenosillo	37°N 6.44°W	Brewer MK-III #150	INTA	June 1997	September 2001
Izaña	28°N 16°W 2400 m a.s.l.	Brewer MK-III #157	INM	May 1992 (#033) July 1998 (#157)	September 2001
Santa Cruz Tenerife	28°N 16°W Sea level	Brewer MK-II #033	INM	Oct 2000	September 2001

Table 1; National Brewer Spectrophotometer network

1.1.2 The UV broadband radiometer network

A national UVB broadband network of 16 Yes-pyranometers (Figure 1), managed by INM, has been fully operational since July 1999. This network was financed by the National R+D Plan of the Ministry of Science and Technology.

Data from each station is submitted daily to the INM's central database and the UV index (UVI) is disseminated by Internet: <http://www.inm.es/web/infmet/tobsr/ulvio/PRIMERA.html>

A primary reference UV pyranometer, located at the Izaña Observatory, and a secondary portable reference UV pyranometer are kept just for the broadband UV network tests. The primary reference instrument participated in a broadband UV detector intercomparison organised by the LAP (Laboratory of Atmospheric Physics) of the Aristotle University of Thessaloniki (Greece) in September 1999. This intercomparison, carried out within the scope of the COST 713 action on "UV-B forecasting", hosted a total of 33 UV broadband detectors from 14 countries.

Comparisons of these pyranometers with double Brewer and Bentham spectroradiometers have been performed at the Izaña Observatory and at the El Arenosillo station. Results show that spectral response calibration facilities must be established. The design of this system is scheduled for 2002 and its implementation for 2003.

1.1.3. *The UVIFAN network*

The group of photobiology and algae biotechnology of the Ecology Department at Malaga University manages the "UVIFAN" UV network, based on broadband Eldonet (European Light Dosimeter Network) radiometers, in the Andalusia region. This network has been financed by the EC FEDER 1FD97-0824 Project. Detailed information of this network can be found at <http://uvifan.scai.uma.es/>

1.1.4. *The Ozone/UV Antarctic network*

In the framework of several projects financed in previous convocations of the National R+D Plan of the Ministry of Science and Technology, three UV-VIS spectrometers (EVA) designed and developed at INTA to measure column NO₂ and O₃ were installed at the permanent Argentinian 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 interesting for the study of polar atmosphere as the southernmost, which is Belgrano, is mostly located inside the vortex, Marambio on the edge, and Ushuaia right outside the vortex. Three multi-channel narrow-band radiometers (NILU-UV) were installed by INM in the same stations in 1999, thanks to the existent agreements of scientific collaboration between INTA, INM, Dirección Nacional del Antártico (DNA/IAA) and Centro Austral de Investigaciones Científicas (CADIC, Argentina). The NILU 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 the joint INTA-INM's "MAR" (Measurement of Antarctic Radiance for monitoring the ozone layer) Project (REN2000-0245-C02-01) financed by the National R+D Plan.

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 NO₂, and UV radiation in order to characterize the polar vortex. A description of the network, including instruments and stations, as well as the results of this network can be found at <http://www.izana.go.to/mar>

1.1.5. *The Global Atmospheric Watch (GAW) Program at the Izaña Observatory*

The Izaña Global Atmospheric Watch (GAW) station, operated by INM, is located at 28°18'N, 16°29'W, 2360 m a.s.l. on the island of Tenerife (The Canary Islands, Spain). The GAW program concerning the ozone and related compounds consists of the following:

- Continuous total ozone monitoring since May 1991, including two Umkehr profiles per day (since January 1992) is performed using Brewer spectrophotometers (see Table 1).
- UV scans every 20 minutes are obtained from the Brewer spectrophotometers since May 1991.
- A double spectroradiometer Bentham DM-150, installed in March 1999, provides global and diffused UV radiation scans every 15 minutes. This is the national UV reference instrument.
- The ECC ozonesonde program was initiated in November 1992. The 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. During intensive campaigns more than twenty sondes per month are launched.
- Meteorological soundings (PTU) have been launched twice per day (at 00 and 12 GMT) since 1958.
- A UV-VIS (DOAS) spectrometer instrument (EVA) from INTA for measuring total column NO₂ and O₃ has been operating at Izaña Observatory since 1993.
- Optical depth (368, 500 and 778 nm) has been measured at Izaña using a PMOD/World Radiation Center (WRC, Davos) sunphotometer since January 1994. Since

June 2001 a Multifilter Precision Radiometer designed at the WRC has been operating at the Izaña Observatory.

1.1.6. The Network for the Detection of Stratospheric Change (NDSC) Program at the Izaña Observatory

Since 2000/2001 the Izaña Observatory has participated in the NDSC network as a complementary station in the following four programs:

- Total ozone with a double Brewer spectrophotometer managed by INM.
- ECC ozonesonde program operated by INM.
- UV-VIS: A photodiode array Spectrograph from INTA has been running at Izaña since December 1998. This instrument is able to measure total columns of O₃, NO₂ and H₂O. Retrievals of Iodine monoxide (IO) are being explored to detect whether or not this radical is in measurable magnitudes in the atmosphere outside of the boundary layer. A new UV photodiode array spectrograph from INTA was installed at the Izaña Observatory in November 2001 to expand the capabilities of the previous ones to BrO. Bromine has 50 times more Ozone Depletion Potential (ODP) than Chlorine and its concentration in the atmosphere is still increasing due to Methyl Bromide (CH₃Br) and Halon emissions.
- FTIR: since February 1999 a ground-based FTIR (Fourier Transform InfraRed) spectrometer (Bruker IFS 120 M) is operated at the Izaña Observatory by the Institut für Meteorologie und Klimaforschung (IMK) (Forschungszentrum Karlsruhe, Germany). Besides zenith column amounts (ZCA) of trace gases such as O₃, H₂O, HDO, N₂O, CH₄, HF, HCl, ClONO₂, NO, NO₂, and HNO₃, profiles of gases with narrow absorption lines such as O₃, NO, HCl and HF can be retrieved.

1.1.7. INTA's station at Keflavik (Iceland)

A long-term ozonesounding program between INTA and IMO (Icelandic Meteorological Office) is running at the subArctic 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 been launched during winter through a number of European projects (SESAME, OSDOC, THESEO) and will continue in the near future (QUOBI).

1.1.8. Long-term ozonesondes station at Belgrano Base (Antarctica)

A long-term ozonesounding program between INTA and DNA/IAA (Argentina) has been running at the Belgrano station (Argentina, 78°S, 35°W) since 1999. Since then and to date ozonesondes have been launched through 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).

1.1.9. Intensive campaigns

INTA and INM 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 is being carried out in connection with the European projects (EASOE, SESAME (OSDOC), THESEO (O₃-LOSS), EUROSOLVE). Sondes are both European and nationally financed.

Two national UV and visible spectroradiometer intercomparisons were held at the El Arenosillo station (INTA) in September 1999 and September 2001, respectively. Solar measurements and lamp calibrations were performed.

INOVO INterhemispheric OCIO Polar VOrtex Variability. An intensive campaign to test the new high-resolution spectrograph and carry out measurements of OCIO and study the impact of high

reflective surface (snowy surface) on the species retrieved during the winter of 2001 at the polar observatory of Sodankyla, Finland. The instrument will be installed at Marambio Base, Antarctica next austral summer. The campaign has been financed by the European Commission through the LAPBIAT infrastructure facility.

1.1.10. Other monitoring programs and activities

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.

INM has run a regular ozonesonde program in the Madrid-Barajas station on a weekly basis since March 1992.

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

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 (sea level) in Tenerife. A comparison of the UV and visible spectra obtained from this spectroradiometer with those obtained from a similar Bentham DM150 installed at the Izaña Observatory (2400 m a.s.l.) will be used to study the connection between UV radiation and radiative properties of the atmospheric aerosols and clouds.

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).

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.

1.2. UVI forecasting

In accordance with the COST-713 action ("UV-B prediction") of the European Commission a H+24 forecasting model of UVI for Spain has been implemented by INM. This model has a resolution of

5'x5' on a geographical domain bounded by 45°N/15°W and 25°N/5°E. The ozone prediction is based on a regression model, and the UVA-GOA radiative model from Valladolid University is used for UVI calculation.

The daily maximum forecasted UVI, as well as the daily variation of UVI under clear skies for each province capital of Spain are reported by internet:

<http://www.inm.es/web/infmet/predi/ulvip.html>

1.3. UVI public divulging

As part of the activities performed by Spain in the framework of the COST 713 Action "UVB forecasting", a "UV-Index for the Public" booklet (in Spanish) has been adapted and expanded with some examples for the Canary Islands region by INM. A printed version of this booklet has been published in collaboration with the Dermatology Department at La Laguna University Hospital of Tenerife (HUC) and the pharmaceutical associations of the Canary Islands. The booklet can be seen as a web page at: <http://www.izana.go.to/uvi>

1.4. Satellite activities

INTA and INM participate in the STREAMER project coordinated by the DLR, Germany. It is a European project from the Earth Observation Program devoted to forecasting ozone and UV-B in the European sector using the GOME/ESA instrument (and SCIAMACHI/ESA in ENVISAT in the future) and meteorological forecasting. The output will be level – 3 products (maps) 24h forecasting of both ozone and UV-B on Internet, available to the public.

1.5. Ozone and UV research

INM and INTA have actively participated in recent years in European projects related to ozone and UV research, which have recently finished or are still in progress. They are as follows:

- REVUE (Reconstruction of Vertical Ozone Distribution from Umkehr Estimates), ENV4-CT95-0161)
- TRACAS (TRANsport of Chemical species Across Subtropical tropopause) ENV4-CT97-0546.
- STREAMER (Small Scale Structure Early Warning and Monitoring in Atmospheric Ozone and Related Exposure to UV-B Radiation), ENV4-CT98-0756.
- QUILT (Quantification and Interpretation of Long Term UV-Visible Observations of the stratosphere) EVK2-CT2000-0059. Devoted to improvements of Spectroscopic data products (NO₂, O₃, BrO, OClO, IO), Revision of the data sets, Modeling and interpretation, etc.
- QUOBI (Quantitative Understanding of Ozone Losses by Bipolar Investigations) EVK2-CT-2001-00129 (2002-2004): The main objective of the project is to test our quantitative understanding of the chemical mechanisms that destroy ozone in wintertime Arctic stratosphere and springtime Antarctic and to improve the representation of these processes in chemical models of the atmosphere.

INM, INTA and the Universities of Barcelona, Valencia, Valladolid and La Laguna participate in two large coordinated ozone&UV-related projects financed by the National R+D Plan of the Ministry of Science and Technology:

- "Measurement and Modeling for the space-time distribution of the ultraviolet solar irradiance in Spain" (CLI97-0345-C05).
- DEPRUVISE (Determination and forecasting of solar ultraviolet Radiation in Spain: influence of ozone, aerosol particles and cloudiness).

2. Future activities

2.1. Monitoring and QC/QA systems

A new UV photodiode array spectrograph from INTA will be installed in October 2002 in Marambio (Antarctica). It will retrieve zenith column amounts of BrO, OCIO).

Cosine response calibration facilities for Brewer and UV broadband radiometers will be implemented at the Izaña Observatory during 2002.

The "Veleta 2002" field campaign will be held in July 2002, in the framework of the DEPRUVISE project, financed by the National R+D Plan of the Ministry of Science and Technology. This field campaign has been designed to obtain experimental data of elevation effects on solar ultraviolet irradiance. For this purpose different radiometers and spectroradiometers will be installed on both slopes of the Sierra Nevada Massif. The stations will cover from sea level to 3400 m a. s.l. on the top of the Veleta Peak. This information will be used to evaluate the aerosol radiative forcing on the solar UV irradiance. Several groups from the Universities of Granada, Barcelona, Valencia, Valladolid, Malaga and La Laguna, and the INTA and INM will participate in the field campaign. A national UV-instrument intercomparison will be held at the Izaña Observatory (INM) in the summer of 2003.

Aerosol optical depth (AOD) will be obtained by INM from the Brewer spectrophotometer network using the direct sun measurements. This information will be used as input in the national UVI forecasting model.

INM (Izaña Observatory) will perform the QA/QC of the UVIFAN network in order to achieve an homogenization of public information provided by both, UVIFAN and the national UV radiometer network (INM).

INM and Instituto de Meteorologia (IM) of Portugal will routinely exchange data and information from their respective Brewer and UV broadband networks.

2.2. UVI forecasting

The UVI forecasting model will be improved by incorporating as predictors forecasted temperature at 150 hPa, 100 hPa and 70 hPa from the ECMWF in the regression ozone model. A parameterized cloud modification factor will also be included using the cloud forecasts provided by the ECMWF. Validation of forecasted ozone and UVI will be validated using the Brewer and the UV broadband national networks. UVI forecasting will be provided to H+48.

2.3. UVI public divulging

During 2002 an intensive campaign to divulge the UVI to the public is planned by the INM in collaboration with the Spanish Cancer Society, and main national TV, radio and newspaper media.

2.4. Satellite activities

A micropulse aerosol lidar (INTA) and ground-based ozone total column measurements by high quality NDSC (INM and INTA) will be used at the Izaña Observatory facilities during heavy Saharan dust storm events during the summer 2002 to find out whether or not the retrieval of satellite operating in backscattering mode such as TOMS and GOME is severely affected by interferences from the absorbent characteristics of mineral aerosols.

2.5. Ozone and UV research

STREAMER-II. INTA participates in a proposal submitted to the European GMES (Global Monitoring the Environment and Security) Programme devoted to the elaboration of H+24 UV and ozone forecasted maps above Europe and research associated to the ozone layer. The new project will focus on operational aspects regarding data management (GIS, Web, etc), climatology of ozone related species and Streamer events on a global scale based on European satellites and 3D modeling. Validation exercises will also be performed to ensure the data and model quality.

NDSC – Double blind intercomparison of OCIO measurements. Within the framework of the QUILT project, a NDSC intercomparison will take place in the winter of 2002/2003 at the polar facility of Andoya, Norway, (68°N). INTA will participate with its instrument. The purpose is to harmonize results and identify possible causes of discrepancy between instruments. Eleven European Institutes involved in QUILT will participate in this campaign. Unofficial comparison of BrO will be carried out as well.

The effects of clouds and the cloud-sea on the spectral UV radiation will be investigated by INM and La Laguna University at the Izaña GAW observatory using radiative models (DISORT/UVSPEC) and in-situ observations made with double spectrophotometers Brewer and Bentham at sea level and 2400 m a.s.l., respectively.
