Site Audit at IASB, 18 – 19 April 2002

Formal Statement

This audit was the fifth in a series of ten similar site visits that will be made within the European project EDUCE. The EDUCE Scientific Secretary performs the audit and is responsible for drafting a confidential summary (which is sent to the site operator and the project coordinator) and a formal report (which is published at the project web pages). The wording of both the summary and the full report has been approved by the site operator. The full terms and scope of the audit are described within the audit definition, which may be retrieved from the project website.

During this audit, a calibration of a Bentham DM150 was observed.

Overview

The Belgium Institute for Space Aeronomy (IASB) was created in 1964, although there has been an observatory at the present site in Uccle (a residential area of Brussels) since 1870. The main function of the IASB is to conduct research in the field of space aeronomy and to provide a public service by collecting and making available information on the terrestrial space environment.

Sporadic ground-based measurements of spectral solar UV irradiance have been made at the IASB automated station (50.80ºN, 04.36ºE, 105 m a.m.s.l.) since 1989. Continuous monitoring began in March 1993.

The site objectives are presently:

- To investigate UVR climatology, including the influence of changes in ozone, aerosols and city pollution, and to determine any trends in UVR
- To investigate the effects of cloud as part of a study of all moderators of UVR
- To provide UVR data for use in a variety of biological applications (e.g., the calibration of biometers)
- To verify forecasts of the UV index
- To provide UV index data to the public via the meteorological office

IASB operates two modified HD10 Jobin Yvon (JY) spectroradiometers, two Bentham DM 150s, and a collection of broadband instruments. The JY spectroradiometers have been used for the routine continuous measurement of spectral UV irradiance since 1993. These are nominally identical to the spectroradiometer that flew on the Solspec mission of 1983, although almost all of its components have been reconstructed during the last decade. The Bentham spectroradiometers were purchased in 1999/2000. One is used in the dark room to provide a monochromatic light source for the measurement of the spectral response of broadband meters (using a stabilised solar simulator as a source). The second will eventually replace the older JY instruments, but is not yet run continuously because of on-going difficulties with the software. The new Bentham is approximately ten times as sensitive as the existing JY spectroradiometer in the UVB region

The JY spectroradiometer records global spectral irradiance from 280 to 600 nm in steps of 0.5 nm (FWHM at 300 nm is 0.488 nm). A complete scan takes about 6 minutes and 40 seconds. Measurements are made every 15 minutes for solar zenith angles less than 100 degrees.

In addition to the spectral instruments, there are three filter radiometers (SPUV-10, Yankee Environmental Systems UVMFR-7, and Biospherical Instruments GUV 511C), four pyranometers, two UVB meters, and one UVA meter.

Various meteorological parameters, including total ozone from Dobson and Brewer measurements and ozone and temperature profiles from balloon sondes, are also available for the Uccle site.

The SPUV 10-channel filter radiometer measures the direct solar irradiance at wavelengths from 300 nm to 1040 nm, and provides data from which the total ozone column and atmospheric turbidity can be retrieved. One of the UVB meters measures the diffuse component by using a shadow band. The pyranometers return an integrated measurement once a minute.

The IASB instruments are installed on a purpose-built roof platform, with a control room and new dark room in the roof space directly below. The existing JY spectroradiometers are removed from the platform and calibrated in a dark room in a separate part of the building. The Bentham spectroradiometer is permanently positioned in the new dark room, connected to the input optics via an optical fibre bundle. The horizon at IASB lies mostly below 5º, except for some treetops to the South-West, which reach 10º to 15º at a distance of about 50 metres.

There are 5 members of staff (scientists, technicians and engineers) who work with the instruments and data on a part-time basis. Between them, they dedicate about 2 days per week to the routine operation. Two members of the group have more than 30 years experience between them.

The operation at IASB is generally well organised. Data are stored on a dedicated and centrally maintained server. The data files are held on a pc in a clearly-structured file system, with backups on CDROM.

IASB was able to present a clear description of the measurement and data analysis procedures, together with the results of their customary application. The standard calibration, measurement and data analysis procedures are carried out according to well-practiced routine. IASB have the resources and experience to achieve their objectives for data collection and analysis.

The UV group at IASB has access to superb laboratory facilities, including the equipment necessary for full characterisation of the spectroradiometers and also for making a full calibration of the broadband instruments with their spectral response. The behaviour and reliability of the many power supplies and shunts available for 1 kW calibrations have been meticulously investigated. One of the new Bentham spectroradiometers is permanently situated in a temperature-controlled dark room beneath the roof platform. The calibration of this instrument requires only the input optics to be re-positioned.

While the calibration facilities are superb, it is clear that some improvements could be made in the area of lamp husbandry. IASB uses a set of three secondary lamps supplied by NIST, but these lamps are now approaching the end of their working lives. There is also some uncertainty in the amount of drift in the output of these lamps. A new set of 3 lamps is presently on order.

IASB have calculated the uncertainties in spectral UV irradiance, and the analysis has been published in REF?

Future Plans include:

- A check on the output of the existing set of calibration lamps will be made on the arrival of a new suite of NIST lamps
- An attempt will be made to analyse the relative drift between the existing working calibration lamps
- The calibration routine will be extended to include an explicit record of lamp burn times, and the voltage across the lamps.

Figures

Figure 1. View from roof platform, looking South-East (spectroradiometer in middle-ground; pyranometer with shadowband & SPUV-10 filter radiometer in background)

Figure 2. Horizon at IASB site (North: 000/360, East: 090)

Summary

- The measuring site is representative of the local environment.

- The measurements made at the site are representative of the local conditions.

- The documentation and record keeping for the instrument operation and data collection is satisfactory. Improvements could be made to the recording of standard calibration parameters. The documentation of instrument characterisation is available on CDROM.

- All procedures relating to data measurement and analysis are demonstrably repeatable and reproducible.

- The facilities and resources available are sufficient for the site objectives to be fulfilled. The laboratory facilities available are superb and the quality and range of instrumentation first-class.

- The analysis of uncertainty in the spectral UV irradiance has been published [Gillotay *et al*., 1997; Gillotay and Bolsee, 2001]. At present, there is no uncertainty analysis made for integrated and weighted spectral irradiance.

- The measurement and collection of data are carried out diligently. Some reservations in the verisimilitude of the existing calibration lamps are being addressed with the purchase of a new suite of NIST secondaries.

Graded results

	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	.11	.12	.13	.14
1		A	B											
2	B	B	B											
3	B	B	A	A		A	B							
4	B	A	A	B	B	B	A							
5	C	C	B	A	D	C	B	C	B	B	B	B	B	
6	B	B	B	B	B	B								
7	B	B	C	B	B	B	B	B	B					
8	B	B	B	B	A	B								

A	Exemplary
B	Satisfactory
C	Could be improved
D	Should be improved
	Not gradeable
	Not assessed

1. Resources and mission statement

1.1. The site mission is to undertake continuous monitoring of spectral and broadband UV irradiance to generate data of sufficient quality for climatological and biological studies, and for the provision of UV index information to the public. The principle objectives of the site are presently:

- To investigate UVR climatology, including the influence of changes in ozone, aerosols and city pollution, and to determine any trends in UVR
- To investigate the effects of cloud as part of a study of all moderators of UVR
- To provide UVR data for use in a variety of biological applications (e.g., the calibration of biometers)
- To verify forecasts of the UV index
- To provide UV index data to the public via the meteorological office

1.2. Current instruments available include:

- 2 modified HD10 Jobin Yvon (JY) spectroradiometers
- 2 Bentham DM 150s
- 3 UVB meters (1 with shadow band)
- 3 UVA meter (1 with shadow band)
- 3 filter radiometers (SPUV-10, YES UVMFR-7, BI GUV 511C)
- 5 pyranometers
- Yankee total sky imager
- Experimental IR cloud detection and imaging system
- A stabilised solar simulator

1.3. There are 5 members of staff (scientists, technicians and engineers) who work with the instruments and data on a part-time basis. Between them, they contribute the equivalent of about 1/3 of a full-time post.

2. Location

2.1. Coordinates for longitude and latitude are available from GPS readings; the altitude is taken from data provided by the Royal Observatory (Uccle being a reference point).

2.2. The horizon has been measured using a theodolite; values are available in spreadsheet file; distances are not given; no estimate of the influence of horizon on measurements of global irradiance has been made.

2.3. The measuring site is representative of the local environment. Local surroundings are urban cover.

3. Operational matters

3.1. A summary of the UVR monitoring activities at IASB is available, including site history, routine measurement activities and representative results. There are no written protocols for normal operation.

3.2. Sufficient manpower is available for the routine maintenance, calibration, data collection and data processing tasks; The equivalent of one third of a permanent post is dedicated to these tasks.

3.3. The primary staff concerned with operation of instruments and calibration are qualified with many years experience.

3.4. Staff changes are infrequent.

3.5. The same calibration and data processing procedures have been in place since 1994. New procedures will be introduced with the commissioning of the Bentham spectroradiometer. (There will be at least 6 months overlap with the existing JY instrument to ensure consistency in the dataset).

3.6. The WMO/GAW guidelines on site quality control are followed.

4. Instrumentation

4.1. The JY spectroradiometer have thorough and comprehensive user manuals. Some records of the instruments' characteristics were difficult to locate, however.

4.2. The spectroradiometer, pyranometer and biometers used for continuous monitoring are more than adequate for the fulfilment of the IASB objectives. Access to a second spectroradiometer helps to maintain data collection during periods of instrument calibration and maintenance and also provides the opportunity for regular simultaneous measurements of spectral irradiance. This is a powerful QC tool, helping to confirm the reliability of a dataset, including the application of error corrections, and simplifying the investigation of unexplained behaviour. Access to calibrated broadband measurements from multiple instruments also improves quality control. IASB also operates many broadband meters, filter radiometers and cloud-detection instruments, all of which provide many useful auxiliary data. IASB has 4 power supplies, 4 voltmeters and 3 shunts for 1 kW calibrations of the spectroradiometers, giving many opportunities for cross-checking.

4.3. The characteristic behaviour of each spectroradiometer (including slit function, cosine response, etc.) is re-evaluated after every modification of the instrument.
4.4. The cosine response for the JY diffusers is measured in 2 planes. Errors arising from the cosine response are not estimated.
4.5. Slit functions are determined from the measurement of Hg spectral lines.
4.6. Instruments are subject to regular maintenance. All modifications, servicing and repair is made on site. There is a daily cleaning schedule.
4.7. Broadband instruments are calibrated on receipt and yearly thereafter. IASB has the facilities for on-site calibration of non-spectral instruments, including the determination of their spectral response, with Bentham DM150 spectroradiometer and stabilised solar simulator. All broadband instruments are run in parallel to ensure consistency.

5. Calibrations

5.1. The new Bentham spectroradiometer has not yet entered regular operation, and the calibration procedures for this instrument are still being developed. The recording of calibration histories could be improved, however. In particular, details of lamp burn times and the voltage across lamps are lacking.
5.2. The new dark room for the Bentham is well equipped, but a little cramped. No investigation has yet been made into the significance of reflection off the laboratory walls during calibrations with 1 kW lamps. There is presently also some uncertainty in the definition of the optical surface of the new domed diffuser. (The older JY instruments are calibrated in a larger dark room, and have flat diffusers). Lamps are stabilised for 40 minutes before calibration (earlier measurements having shown that output is not stable after 20 minutes). Extensive investigation has been made into the stability and reliability of the 4 power supplies. The future calibration routine will include a correction for the temperature dependence of the shunt.
5.3. The shunt was bought in 1994 and will be re-calibrated later this year. There are 4 certificated voltmeters, one of which was purchased in the last 12 months. A detailed and comprehensive intercomparison of these instruments shows all are stable to within 1 part in 10^6/year. IASB holds 3 NIST secondary lamps. The burn time of these lamps is approaching 100 hours. A new set of lamps is on order.
5.4. IASB uses 3 certificated lamps purchased directly from NIST.
5.5. At present, neither the lamp burn times nor the voltage across the lamps are recorded. While there is regular comparison between the lamps, the possibility of a systematic drift in the power output of all 3 lamps with age cannot be excluded. This is particularly important, given the age and high burn-times of the lamps.
5.6. The lamps used at IASB are supplied directly from NIST. One of the lamps was purchased in 1980; two date from 1994. Each of the lamps is approaching a burn time of 100 hours. A new set of 3 NIST lamps is on order.
5.7. Differences between the existing lamps are 6% to 10%.
5.8. Regular comparisons are made between all 3 lamps. No procedures are in place for the routine determination of lamp drift.
5.9. 1 kW calibrations are performed approximately every second month.
5.10. Typical instrument drift between calibrations is less than 3% to 5%;

5.11. Evidence that the calibration is reliable at the quoted level of accuracy – not examined;
5.12. A dedicated and well equipped dark room permit repeatability and consistency in the calibration regime. Some open questions remain over the possible importance of stray light and the verisimilitude of the calibration lamps.
5.13. The SHICrivm algorithm is regularly applied for controls on the wavelength calibration.

6. Measurement regime

6.1. Adequate documentation exists for the standard measurement regime, which has remained unchanged over the last 10 years.
6.2. The standard operating procedures ensure sufficient data are collected in a reliable and repeatable manner.
6.3. Global spectral irradiance data are recorded four times an hour for solar zenith angles below 100 degrees. These data are supplemented with pyranometer and broadband UV measurements. Information on the UV index, MED values, ozone column depth, aerosol optical depth and standard meteorological observations is also available.
6.4. Global spectral irradiance is recorded FROM 280 to 600 nm in steps of 0.5 nm (FWHM at 300 nm is 0.488 nm). A complete scan takes about 6 minutes and 40 seconds. Measurements are made every 15 minutes.
6.5. IASB operates 2 identical spectroradiometers for routine measurements, so that calibrations and routine maintenance do not interrupt measurements.
6.6. All aspects of the routine measurement regime are demonstrably repeatable.

7. Data Analysis

7.1. Data analysis procedures are simple enough to remove the need for extensive documentation.
7.2. The SHICrivm algorithm is regularly applied to calibrated data.
7.3. No analysis of cosine errors has been made. The influence of the local horizon on measurements has not been estimated, but is expected to be small.
7.4. Wavelength errors are routinely analysed using the SHICrivm algorithm. No correction for cosine response is made (in previous intercomparisons, better agreement has been found if the cosine response is not applied).
7.5. Broadband measurements are used in regular quality control.
7.6. An estimate of the uncertainty budget for the JY spectroradiometer has been made and published [Gillotay *et al.*, 1997; Gillotay and Bolsee, 2001].
7.7. No estimates for the uncertainties integrated values have yet been made..
7.8. Any changes to the irradiance scale or standard error-correction procedures are applied retrospectively to the entire data set.
7.9. Data are stored on pc and tape. At the end of each year, all data are copied to CDROM, including Flexstor files and auxiliary information such as meteorological observations and data products. Older versions of data are kept. stored on a central server.

8. Quality management

8.1. Standard data products, such as erythemal daily dose and UV index, and also comparisons of integrated spectral with broadband measurements are regularly plotted.

8.2. There is regular processing with the SHICrivm algorithm for control of wavelength errors. Regular comparisons are also made of spectral measurements with the UVB and UVA broadband data and output from the multifilter radiometers.
8.3. The SHICrivm algorithm.
8.4. Ideas are taken from the WMO/GAW guidelines on site quality control of UV monitoring.
8.5. The JY spectroradiometer has taken part in many national and international intercomparisons, including:
- CAMSUM (Ispra 1995)
- Brussels laboratory campaign (1996)
- SUSPEN (Ispra, 1997)
- Nea Michaniona (1997)
- Biodos (Hungary, 1997)
- Garmisch-Partenkirchen (1998)
- Crete/PAUR II (1999)

Future intercomparisons are planned with USTL and UJF.

8.6. At the time of the audit, only one data version existed.
8.7. None.

References

Gillotay, D., J.F. Muller, B. Walravens and P.C. Simon, “The Influence of different types of cloud layer on the UV-B climatology in Belgium”., *in* IRS '96: "Current Problems in Atmospheric Radiation", Eds W.L. Smith and K. Stamnes, Fairbanks, USA, August 19-24, 1996, pp 921-924, A Deepak Publishing, 1997

Gillotay, D., D. Bolsee, “The UV climatology in Belgium from UV Field monitoring”, *in* IRS 2000: "Current Problems in Atmospheric Radiation", Eds W.L. Smith and Y.M. Timofeyev, St. Petersberg, Russia, 24-29 July, 2000, pp 1162-1165, A Deepak Publishing, 2001

IASB comments