Standard Operating Procedures (SOPs) for Spectral Instruments Measuring Spectral Solar Ultraviolet Irradiance
STANDARD OPERATING PROTOCOLS (SOPs) FOR
SPECTRAL INSTRUMENTS MEASURING SPECTRAL
SOLAR ULTRAVIOLET IRRADIANCE

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ACKNOWLEDGEMENTS
The Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization (WMO) is an international programme supporting long-term observations and analysis of the chemical composition and physical properties of the atmosphere that are relevant for understanding atmospheric composition and climate change. The mission of the Programme as summarized in the “WMO Global Atmosphere Watch (GAW) Strategic Plan: 2008-2015” (WMO, 2008) is: 1) to make reliable, comprehensive observations of the chemical compositions and selected physical characteristics of the atmosphere on global and regional scales; 2) to provide the scientific community with the means to predict future atmospheric states; and 3) to organize assessments in support of formulating environmental policies.

Solar Ultraviolet Radiation is one of the focal areas within GAW. The main objective of this group is to provide better predictions of UV intensities at the Earth's surface both in populated and remote regions. Harmonized, quality controlled observations of UV irradiance constitute the basis to improve UV radiation levels forecasting.

The quality assurance system developed within the GAW Programme provides a framework to reach the required harmonization of observations performed by different GAW laboratories. The most recent QA framework is described in the “WMO Global Atmosphere Watch (GAW) Strategic Plan: 2008-2015” (WMO, 2008).

The Quality Assurance system of GAW consists of a number of elements and requires for its implementation

- The establishment and maintenance of a single reference scale (primary standard).
- The establishment of the procedures linking observations to the primary standard (including measurement guidelines (MGs) and standard operating procedures (SOPs), calibration procedures, guidelines for station audits and set up of comparison campaigns).
- Specification and rolling review of the Data Quality Objectives (DQO) and observational network by the designated Scientific Advisory Group (SAG).
- The use of harmonized terminology.

The GAW Scientific Advisory Group for UV Radiation (SAG UV) was charged with developing SOPs for the different categories of UV instruments. This publication is relevant for instruments that resolve the spectral detail of solar UV radiation. A primary goal of this document is to assist in harmonizing UV spectral measurements from all GAW stations. It provides practical guidelines on instrument operation and maintenance as well as details of data protocols to follow within the GAW network. It is also applicable to other UV monitoring networks or a single site of UV measurement.
1. SCOPE AND APPLICABILITY

Solar ultraviolet (UV) radiation represents only a few percent of the total solar spectrum. Due to its high photon energy, it has important effects on human health, atmospheric photochemical reactions and biological ecosystems (Zerefos and Bias, 1997). The level of the UV-B radiation (280-315 nm) at the Earth’s surface, with high photon energies and inherently damaging effects, is essentially controlled by stratospheric ozone. During the past three decades scientific research has shown that stratospheric ozone over much of the globe has been depleted to some extent, thus increasing the surface UV radiation in many parts of the world (Farman et al., 1985; Kane, 1998; Smedley et al., 2012).

Regarding human health, excessive exposure to UV radiation increases risk of skin cancers, causes cataracts and reduces the effectiveness of the immune system. However, moderate UV exposure can have the well-known beneficial effect of initiating vitamin D synthesis in the skin. In an example of another biological system, increased UV radiation reduces growth and photosynthesis of several plant species. The effects of UV radiation and interaction of the radiation with atmospheric components depend on its wavelength. To quantify these impacts of UV radiation, accurate solar spectral UV irradiance data are required. As a result, measurements of spectral UV irradiance are currently performed in many parts of the world by using different types of spectroradiometers. In order to obtain reliable and accurate spectral UV irradiance data and to harmonize the measurements, SAG UV and the UV Instrumentation Subgroup has defined spectral instrument specifications for several tasks and guidelines for instrument characterization (GAW Report No. 25 [WMO, 2001]), and more recently for diode-array spectroradiometers (GAW Report No. 191 [WMO, 2010]). In order to use a spectroradiometer and obtain high quality spectral data, appropriate operating procedures are required.

This document outlines such operating procedures for spectral UV measurements and is intended for use by station operators. As it does not present the details of instrument characterization and calibration, the guide should be used in conjunction with GAW Reports No. 125 [WMO, 2001], No. 126 [WMO, 1998], No. 146 [WMO, 2003], and No. 191 [WMO, 2010] providing more detail and background information.

Note that these operating procedures are written with respect to the scanning, double monochromator spectroradiometers defined in GAW Report No. 125 [WMO, 2001]. However, the principles apply equally well to the more recent diode array spectrometers. For diode array instruments additional requirements need to be fulfilled (GAW Report No. 191, [WMO, 2010]).

2. INSTRUMENTATION

Referring to GAW Report No. 125, the spectral UV instruments are classified into two types: type S-1 and type S-2 according to their purposes and uncertainty. The type S-1 instrument has data quality objectives of establishing a UV climatology and providing public information (e.g. actual UV level and a UV index), while the type S-2 instrument might be further employed for detection of UV irradiance trends and validation of radiative transfer models and satellite-derived surface UV irradiance. Thus the greatest accuracy is required of type S-2 instruments. The guidelines for operating procedures remain the same for both types S-1 and S-2.

Although there are a variety of spectral UV instruments, they commonly consist of four main parts: input optics (i.e., diffuser or integrating sphere), a wavelength dispersion and alignment system (filter wheel, grating monochromator), a detector (photomultiplier or silicon diode) and a control and logging system (computers).
Instrument details should be listed in a logbook on site. These include the make and model, serial number, the instrument specifications, details of deployment and site specific information (e.g. obstructions in the hemispheric field of view, and the calibration history). More details on such record keeping can be found in GAW Report No. 126 [WMO, 1998].

3. INSTALLATION

The first consideration of installation is safety, of both the instrument and the operator who will be required to perform daily maintenance, including access to the input optics of the instrument. In general, the instrument must be securely mounted in such a way that it should not be damaged by any weather conditions expected locally, operator access is safe in all conditions, and there is no danger from associated electrical supply as photomultiplier tubes require high voltages. The installation site must be carefully selected to ensure that the input optics are not shaded by local objects at any time of day and year, nor are they subject to reflections from nearby surfaces, or to interference by artificial lights. Since there are several varieties of spectroradiometers, more specific advice on installation and operating procedures will depend on the instrument design, of which there are three basic types:

- Moving body with integral optics (MBIO)
- Non-moving body with remote optics (NBRO)
- Non-moving body with integral optics (NBIO)

The body means that the container usually houses the monochromator and detector together. More detailed conditions of site selection, mounting, orientation and cabling need to be considered separately for each type of instrument.

3.1 Moving body with integral optics (MBIO)

An instrument with moving body rotates in order to track the sun, with the purpose of making direct sun measurements from which various atmospheric properties can be derived. The input optics (including those for global UV radiation) rotates with the body of the instrument. The schematic components of a MBIO are shown in Figure 1. Of necessity, the body of the instrument is mounted outdoors, and must be both insensitive to a wide range of weather conditions and located in a space sufficient to allow free rotation. The mounting platform must be firm and free of warping or motion, with no danger that the instrument base can shift, since alignment is vitally important for sun tracking.

![Figure 1 - The schematic components of a MBIO](image-url)
Installation requires precise alignment of the tracking system, either by exact geographical alignment of one feature of the instrument (e.g. align one side to north), and/or an iterative manual or computer controlled adjustment. For the purposes of global UV irradiance measurements, the input optics must view the full sky hemisphere, so other than levelling of the instrument further alignment is not crucial. Nonetheless, the instrument is usually required to fulfill all its functions and this becomes part of its overall operation (GAW Report No. 126 [WMO, 1998]).

Since the instrument is mounted outdoors, the access to power, and the connection to control and logging systems must be considered. To prevent signal interference and electrical hazards, all cables must be securely sealed with appropriate cable protection, and routed along a suitable path, avoiding trip hazards and protecting the equipment from the elements (e.g. heavy rain/flooding of ducts, high winds, ice accumulation).

For long-term observations, a power backup system for the computer is recommended to avoid data loss in the event of power failures.

3.2 Non-moving body with remote optics (NBRO)

If the input optics is remote from the monochromator body of the instrument, then the optics is the only part of the equipment that needs to be exposed to the sky hemisphere. The main body of the instrument can be maintained in a protective environment (building), close to power and the control and logging equipment. A light guide can be used to direct the light collected by the input optics into the monochromator, and such light guides (e.g., quartz fibre optics, for use in the UV) can be many meters in length. Installation procedures now require that only the input optics be securely mounted outside, in such a way that they can be levelled, but then fixed so that they do not move. Any tower or platform used to mount the input optics must be attached firmly to a stable fixture (floor or wall). The sensor should ideally be placed at a height of about 1.5 m above the platform surface, allowing the operators to clean and check the dome with ease.

The connection to the monochromator (fibre optic routing) must avoid the same hazards as the cabling of the MBIO, i.e. safe from the elements, not a danger to operators. Since fibre optics may be damaged by bending in a tight radius, twisting and crushing, the route of the fibre must be carefully planned and it is recommended that the fibre is well protected and held gently but firmly in place along its route. Even gentle curves in a fibre optic can in some cases influence its transmission characteristics. Operators should be aware of the performance of the fibre and the limits on its position for consistent transmission and hence overall sensitivity of the instrument.

The monochromator and detector do not require the same exacting design against the elements as the MBIO. Since the basic instruments are often designed for laboratory use, care must be taken that they are not sensitive to conditions (e.g. in a field hut) that may be less stable than a carefully controlled laboratory. These instruments generally require a temperature stabilization system to maintain a consistent performance under all external conditions.
3.3 Non-moving body with integral optics (NBIO)

Instruments with integral optics but without a tracking feature (i.e. non-moving body) are often designed as portable instruments, where field use is intended. Like the NBRO, they generally require temperature stabilization for stable performance, but the requirement to have the integral input optics free of obstruction and with a clear view of the sky is getting more challenging.

Where such instruments are used, either temporarily or permanently, they have the same cabling issues for power and control as the MBIO, and the instrument should be mounted on a firm platform (e.g. a suitable block or table) where it can be levelled and secured, but at a height enabling safe operator access for maintenance.

For any other instrument type, the operator should consult the manufacturer for any specific installation requirements.
4. DATA ACQUISITION

The raw data retrieved from the spectroradiometer logging system is usually in terms of analogue data. These data are then converted to digital data. The best, currently achievable, uncertainties of spectral UV irradiance measurements are ±5%, resulting from uncertainties due to the instrument temperature, wavelength alignment, sampling interval, spectral and cosine responsivities, and the underlying calibration standards. In practice, good management of the factors described in the following paragraphs will help to reduce additional uncertainties in the data.

4.1 Time stamp

It is important to ensure that the time stamp of each single measurement is always correct. The time should not differ by more than 10 seconds from standard local time. An automatic timer system is recommended for installation in the computer (and synchronized with internet time server if possible). In the case of a standalone data logger, the time stamp must be manually corrected at least every week, or more often if experience demands it (some computer clocks show an offset of as much as 5 minutes per day), by reference to a local radio clock or the Global Positioning System (GPS) time.

4.2 Data averaging

Any average over the specific time period should be consistent with requirements of the network. Standard deviation, minimum and maximum values of each averaging period must be provided with the averaged data.

4.3 Measurement frequency

Most currently deployed spectral instruments scan across the spectrum sequentially from the shortest to longest wavelength, meaning that a spectrum is gathered over a finite interval of time (this does not apply to diode array instruments which gather a spectrum almost instantaneously). The time interval between wavelength steps may be constant, or may change with fixed waveband, or interactively according to signal levels. In general, the scanning process of spectral measurements consumes several minutes, the exact time depending on the wavelength range covered and step size (wavelength interval sampled). Scan time has to be balanced against data collected, and is also dependent upon instrument hardware and software. A scan time of less than 10 minutes is recommended.

4.4 Instrument temperature

It is important to maintain a constant temperature for the electronic and optical parts of the instrument that are known to be temperature sensitive. This usually includes the photomultiplier tube, and the double monochromator, and may also include other electronic components. GAW Report No. 125, recommends that the temperature inside the instruments should be continuously monitored and controlled to a stability range of ±2 °C. Diode array instruments can be equally susceptible to changing temperatures, albeit for different reasons, and should be considered in need of temperature stabilisation.
5. DATA PROCESSING

Spectral instruments produce a wavelength dependent electrical signal ($U_\lambda$), sometimes called the digital count. This series of output signals is related to the magnitude of incoming solar irradiance at each wavelength. The values of $U_\lambda$ obtained from the instrument must be converted into absolute values of spectral solar irradiance ($Wm^{-2}nm^{-1}$) by using conversion factors (the spectral calibration). Details of the different calibration procedures, including external validation, are provided in GAW Reports No. 125, 126 and 146. Scanning spectroradiometers are not known for their stability and calibrations should be checked frequently (e.g. weekly/monthly, or as experience dictates). This is usually achieved by measuring a lamp of known output with traceability to a National Standards Laboratory, in situ.

Measurements of spectral solar irradiances ($I_\lambda$) can be derived using the raw signals and conversion factors ($C_\lambda$), as follows:

$$ I_\lambda = (U_\lambda - U_o) \cdot C_\lambda $$

where

$I_\lambda$ = spectral solar irradiance ($Wm^{-2}nm^{-1}$),
$U_\lambda$ = raw signal measured by the instrument,
$U_o$ = offset signal measured for dark condition,
$C_\lambda$ = calibration factors, expressed as a function of the wavelength.

It is imperative that the wavelength alignment of the instrument is correct both during the calibration and the measurement (i.e. that spectral irradiance is assigned to the correct wavelength). Further corrections to the measurement may then be required to account for imperfect cosine response of the input optics, stray light and non-linearity of the instrument (see accompanying GAW Reports No. 125, 126 and 191)

In order to assess biological effects of UV radiation, the spectral irradiance ($I_\lambda$) can be weighted with an action spectrum for the corresponding effect, e.g. erythema or DNA damage.

$$ E_{\text{weighted}} = \int_{\lambda_1}^{\lambda_2} I_\lambda R_\lambda d\lambda $$

where

$E_{\text{weighted}}$ = the biological effective irradiance ($Wm^{-2}$),
$I_\lambda$ = the spectral irradiance ($Wm^{-2}nm^{-1}$),
$R_\lambda$ = the biological weighting function,
$\lambda$ = wavelength (nm).
6. HEALTH AND SAFETY WARNINGS

The following procedures are intended to avoid personal injury.

- High voltage electrical supplies must be clearly labelled.
- Some desiccants, e.g. blue silica gel, are toxic. Where these are still in use personnel must be advised of the dangers and safe handling procedures followed.
- Instruments installed at height, e.g. on a rooftop, must be well secured. Any high monopods or towers employed in mounting the detectors must be firmly secured, e.g. with the ground anchors.
- Elevated access to instruments or input optics should be secured with guard rails or similar safety measures to protect personnel working at height.
- The lamps used for calibration, both in the laboratory and in the field, have by necessity a UV output. Personnel should protect skin and eyes from prolonged exposure to radiation from the lamps.
- Personnel servicing the instruments may on occasion spend prolonged periods outdoors. Different climates can produce different hazards in these circumstances. Personnel should be advised and protect against site specific hazards, e.g. sunburn, hypothermia, slip hazards.

7. INSTRUMENT ROUTINE MAINTENANCE

Routines for instrument maintenance described in this section closely follow those in GAW Report No. 125. The following regular procedures are recommended to ensure that the instrument maintains optimum performance.

Note that these tasks should, where possible, be performed when the instrument is not actively scanning. Any maintenance operation that disturbs a measurement should be noted in the instrument log.

7.1 Daily maintenance

- Clean the quartz dome and entrance optics.

  The quartz dome and entrance optics should be cleaned as early as possible in the morning to remove any dew, frost or ice. If the dome or the entrance optic is damaged, cracked or broken, it should be replaced.

- Visually check for condensation in the dome.

Check or change desiccant and note in instrument log.

- Perform dark current offset test.

This task should be performed when no radiation is falling on the input optics (e.g. during darkness, or using a shutter either externally or integral to the instrument).

- Check output signals where appropriate (e.g. if visually displayed on a monitor).

Any obvious abnormally is most easily spotted if the scan is displayed graphically.

- Check the control and logging system (e.g. software operating, memory sufficient).
7.2 Weekly/Monthly maintenance

- Inspect the time stamp on the computer/data logger and correct (if necessary) using local radio clock or a GPS system.

If experience shows that this task needs more frequent attention then move to daily checks. The time should not differ from the reference time by more than 10 seconds.

- Check humidity indicator and change the desiccant if necessary.
- Check temperature stability.
- Check levelling the instrument or input optics as appropriate.
- Check power supply and backup system.
- Inspect all connectors and cabling and repair if necessary.
- Check tracker (pointing to the sun), if necessary.

In addition, the following procedures should be performed (refer to the specific instrument manual and GAW reports No. 125 and 126 for details):

- Determine/check the spectroradiometer's bandwidth. This is particularly important if the instrument has variable slit widths that might have moved.
- Check the wavelength alignment using a standard mercury lamp or Fraunhofer absorption line spectra.
- Perform a sensitivity check of the spectral responsivity with field calibration lamps (e.g. quartz halogen lamps).

7.3 Yearly maintenance

- Perform a sensitivity check using a reference standard lamp.
- Perform a stray light test.
- Send the site standard lamp to be externally validated where necessary, or cross-check against other standards on site (it is recommended that a minimum of 3 lamps of equal standing be maintained on site). All lamps should be checked every 50 hours of use, and this should be stated on the calibration certificate.
- Check the angular response of the spectroradiometer.
- Characterization of linearity and offsets.
- Check instrument stability by comparison to a standard reference detector, or other equivalent external intercomparison (frequency no less than every 4 years, but as often as possible).

Note that if the instrument is moved, all the installation requirements apply to the new position, and the instrument calibration must be checked in the new position since movement can disturb delicate mechanical, optical and electrical settings.

8. DATA MANAGEMENT AND LOGBOOK ENTRIES

Details of instrument identification and metadata records including unusual or anomalous weather conditions, system failure and name of the operator, should be recorded daily. Data should be backed up locally on a daily basis and the raw data should always be kept, as well as any processed final output. During long-term monitoring, detail and history of any changes must be logged, including calibration dates, changes to sampling interval, software, hardware, cabling and data logger. Any alteration to any part of the system should be noted.
Where instruments are installed in a remote place and not on-site, a wireless communication system including GPS, SMS and warning alarm, which allow the operators to monitor the instrument, re-set or alter its schedule and download the data, should be provided. In this case data should be downloaded to a separate backup storage everyday.

Daily maintenance and instrument settings should be recorded in a secure and retrievable manner, e.g. a notebook, or a computer file (with back up). A hard copy checklist is most convenient for use as the tasks are performed. A maintenance check list and logbook for spectral instruments are provided below as examples:

**Example checklist**

**Spectral Instruments**

**Logbook Weekly Entries**

<table>
<thead>
<tr>
<th>Station Name:</th>
<th>Data:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Time:</td>
<td></td>
</tr>
<tr>
<td>Name of Operator:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Check list</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>Vertical Alignment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Desiccant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cleaning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cabling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tracker</td>
<td></td>
</tr>
<tr>
<td>Monochromator</td>
<td>Temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Humidity</td>
<td></td>
</tr>
<tr>
<td>Data logger/ Computer</td>
<td>Time stamp</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time shift correction</td>
<td></td>
</tr>
<tr>
<td>Power Supply</td>
<td>Check power supply</td>
<td></td>
</tr>
<tr>
<td>Calibration Check List</td>
<td>Spectral Response</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wavelength alignment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bandwidth (if required)</td>
<td></td>
</tr>
<tr>
<td>Metadata</td>
<td>Sky condition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weather condition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ambient temperature</td>
<td></td>
</tr>
</tbody>
</table>
**Example checklist**

**Spectral Instruments**

**Logbook Daily Entries**

Station Name: ______________________

<table>
<thead>
<tr>
<th>Date</th>
<th>02-Jan</th>
<th>03-Jan</th>
<th>04-Jan</th>
<th>05-Jan</th>
<th>06-Jan</th>
<th>07-Jan</th>
<th>08-Jan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Julian Day</td>
<td>002</td>
<td>003</td>
<td>004</td>
<td>005</td>
<td>006</td>
<td>007</td>
<td>008</td>
</tr>
<tr>
<td>Operator</td>
<td>GD</td>
<td>CC</td>
<td>GD</td>
<td>GD</td>
<td>GD</td>
<td>GD</td>
<td>GD</td>
</tr>
<tr>
<td>Time Shift(1) (sec)</td>
<td>+9</td>
<td>+10</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
<td>-3</td>
<td>-4</td>
</tr>
<tr>
<td>Time Corrected(2)</td>
<td>No</td>
<td>+1</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Cleaning</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Desiccant check</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Cabling</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Dark offset</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Output Signals</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Logging and Control system</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Collector Conditions(3)</td>
<td>C</td>
<td>C</td>
<td>W</td>
<td>C</td>
<td>R</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Sky Conditions(4)</td>
<td>C</td>
<td>P</td>
<td>O</td>
<td>C</td>
<td>O</td>
<td>C</td>
<td>P</td>
</tr>
</tbody>
</table>

(1), (2) If GPS or other time control/correction device is not provided with the system.
(2) Only when required
(3) (C=clear, S=snow, W=water, F=frost, L=light, H=heavy, R=raining, D=dust)
(4) (C=clear sky, P=partly cloudy sky, O=overcast sky))

**Error messages:**
"1/8/06 5:58:23 AM, GPS communication error"

**Special Events**
"1/3/06 12:50:01 PM, run absolute scan lamp m698 (CC)"
REFERENCES


ACKNOWLEDGEMENTS

We gratefully acknowledge the members of WMO Scientific Advisory Group (SAG) on UV monitoring for their helpful contributions and comments.

_______
LIST OF RECENT GLOBAL ATMOSPHERE WATCH REPORTS*


104. Report of the Fourth WMO Meeting of Experts on the Quality Assurance/Science Activity Centres (QA/SACs) of the Global Atmosphere Watch, jointly held with the First Meeting of the Coordinating Committees of IGAC-GLONET and IGAC-ACE, Garmisch-Partenkirchen, Germany, 13 to 17 March 1995 (WMO TD No. 689).


113. The Strategic Plan of the Global Atmosphere Watch (GAW) (WMO TD No. 802).


* (A full list is available at http://www.wmo.int/pages/prog/arep/gaw/gaw-reports.html)


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