Annex 5

REPORT

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Participation in the NRPA Intercomparison of Multiband Filter Radiometers

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1 Purpose of Short Term Scientific Mission

The purpose of this Short Term Scientific Mission was to participate in the NRPA Intercomparison campaign, held in Østeras, Oslo, Norway. Among my tasks was the overseeing of the proper operation of GUV and NILU-UV instruments and their synchronization and performing daily inspections. More important was the participation in the calibration of the instruments, which included spectral and angular response characterization. Finally, some assisting in the first steps of the data analysis and evaluation of the characterization results was provided.

In this report the following topics are presented:

a) General information concerning the NRPA campaign, its purpose, and the instruments and institutes that participated
b) Description of the spectral response and angular response characterization units, as well as information on the calibration procedures.
c) Description of the pre-analysis needed for the data, in order for them to be later processed.
d) Some first results of the evaluation of angular response data, together with analysis of the physical significance of these results.

2 The NRPA Intercomparison of Multi Filter Radiometers

The NRPA Intercomparison of multiband filter radiometers was a part of a national project, '***Factors affecting UV Radiation in Norway***' and was hosted by the Norwegian Radiation Protection Authority (NRPA) in cooperation and under the funding of the World Meteorological Organization (WMO) in Oslo, from the16th of May to the 3rd of June 2005. The purpose of the intercomparison included:

- To validate global UV-index from different national UV-monitoring networks utilizing multiband filterradiometers.
- To intercompare UV measurements from Norwegian GUV's after 10 years operation.
- To exchange experiences and knowledge among MBFR users

- To improve accuracy in measurements of UV Index
- To establish a harmonized UV-index scale among MBFR networks

The intercomparison was held under the support of

- The Research Council of Norway
- COST-726
- WMO

3 Instrumentation

Among the instruments that took part in the NRPA Intercomparison different kinds were included. Totally, 37 instruments participated in the campaign:

- 15 NILU-UV Radiometers
- 16 x GUV (3 from outside Norway)
- 2x UV multiband rotating shadowband RM
- 3x Bentham DM150 spectroradiometers
- 1x Bentham DM300 spectroradiometer

In detail, all instruments and the institutes are shown in Table I. The instruments were all placed in the solar platform on the roof of the NRPA building (Fig. 1)

Figure 1 : The solar platform with -mult-ifilter radiometers

TABLE I: Instruments from different institutes participating in the NRPA campaign

Country	Institution	Instruments	No of instruments
MBFR			
Finland	Finnish Meteorological Institute, FMI	NILU-UV6T	2
Sweden	Swedish Radiation Protection Authority, SSI	GUV	1
USA	Colorado State University, USDA	UV-MFRSR	2
Poland	Institute of Meteorology and Water Management	NILU-UV	1
USA	Biospherical Instruments	Prototype GUV	1
Belgium	Belgian Institute for Space Aeronomy	NILU-UV	1
Spain	INSTITUTO NACIONAL DE METEOROLOGIA	NILU-UV	2
England	University of Manchester	GUV	1
Greece	Aristotle University	NILU-UV	1 (+6 later characterised)
Norway	NRPA & NILU	12x GUV	12
Norway	NILU	2x NILU	2
Norway	UiO/UiB	6x NILU	6
Norway	NTNU	1 GUV	1
Spectroradiometers:			
Austria	CMC Ing. Dr Schreder	Bentham 150	1
Norway	NTNU	Bentham 150	1
Norway	NRPA	Bentham 150	1
Norway	NRPA	Bentham 300	1

4 Synchronisation, data aquisition, sampling frequency and data retrieval

- The spectroradiometers were operating according to the QASUME protocol
- There was a local PC network, each PC operating 7 to 10 MBFR's using hyperterminal.exe and Daswin-emulating software
- The averaging time was 1 sec for the NILU-UV meters and 10 sec for the GUVs, with a 60 seconds averaging period for bothtypes of instruments
- Daily upload to ftp server zardoz.nilu.no, from where users may access their own data.
- Assistance from 2 STSM's within COST-726

5 Spectral response characterization

A specially designed unit performed the spectral response characterization of the instruments. The unit consisted of a 1000W Xe arc lamp, two monochromators, a reference detector, whose spectral response is known, and two mirrors. (Fig. 2). The basic idea of the spectral response characterization is the measurement by both the instrument and the reference detector, of all wavelengths that are included in the each instrument's wavelength range.

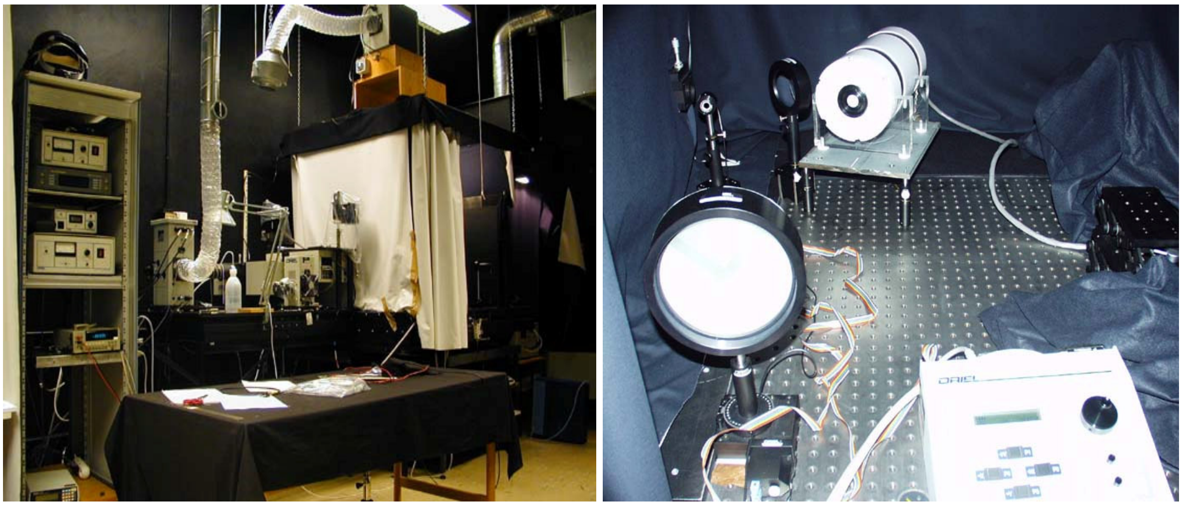

Figure 2: The spectral response characterization unit (Lamp and monochromator on the left, instrument, detector and mirrors in dark room on the right)

The light is directed from the lamp to the dark chamber where the instrument is placed. The wavelength of each measurement is automatically selected, starting at 270 nm and reaching 700nm in steps of 1nm. A measurement with closed shutter is performed before each wavelength measurement to monitor the dark level during the procedure. Each measurement lasts 60 seconds and some waiting time is interceded before the measurement (20 seconds for the NILU-UV instruments, 10 seconds for the GUV instruments and 2 seconds for the reference Si detector) in order for all instruments to adjust to the changes in their illumination.

Using the two mirrors, the light is directed towards the instrument, the measurement is performed and then automatically the placement of the mirrors changes and the light is directed towards the detector. The whole procedure is made for two sets of slits, one corresponding to1.6 nm FWHM band pass and another corresponding to 5.0nm. Both responses are used to extract the final spectral response of the radiometer.

6 Angular response characterization

The angular response characterisation unit requires a different configuration. The instrument is placed on a rotating table, which enables the turning of the instrument in steps of even less than 1 degree. A 150W Xe arc lamp is used as a light source. The alignment of instrument requires special attention concerning the following:

- The incident angle of 0 degrees must be correctly set on the rotating table in the position where the light falls vertically in the instrument diffuser.

- The horizontal and vertical position of the instrument should be adjusted so that the diffuser is fully illuminated. Special care is taken to avoid the illumination of the diffuser from the brighter part of the lamp image, to ensure as much homogeneity as possible.

- The distance of the instrument diffuser from the light source should be adjusted so that the light illuminates the diffuser in all positions. More specifically, when the instrument is turned to 90 degrees, the side of the diffuser should appear to be in the centre of the lamp image.

After the instrument is aligned, it is placed in the 90 degrees position for the angular response characterization. Measurements are taken in 90, 88, 85, 80, 75, 70, 60, 50, 40, 30, 15, 0 degrees and each measurement lasts 60sec. Similarly to the spectral response characterization, the dark is measured before the actual measurement in each angle and is later subtracted from the measurement values.

The angular response characterization is repeated for four azimuthal cross sections; North-South, North West- South East, West-East and South West-North East, namely for a step of a 45 degree rotation of the instrument around its axis.

7 Data pre-analysis

As it has been mentioned previously, both the measurements of spectral and angular response are interrupted by dark measurements. As a consequence, the data have the following form when plotted:

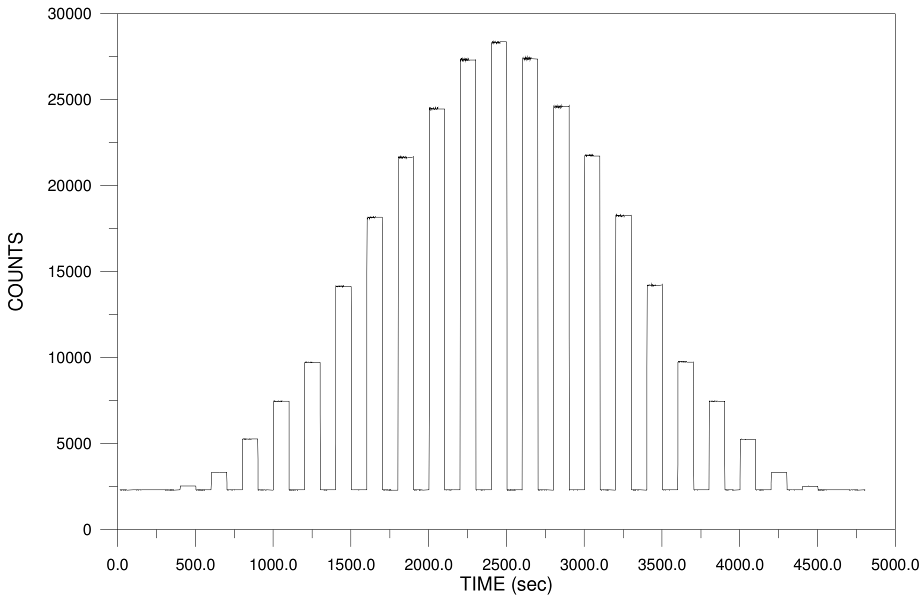

Figure 3: Raw counts of an angular response measurement versus time

To enable the automatic process of the data, some pre-analysis was necessary. A mean value from each measuring interval is calculated, leaving out the first and last 5 or 10 seconds of the measurement to take into account the instrument's response time. The same is done for the periods of dark measurements as well, and the dark mean value (in this case in each angle of incidence) is subtracted from the corresponding measurement of the response.

In this pre-analysis of the data, some cases where individual measurements lasted for a longer time period should also be corrected so that all files are in the same format. After the pre-analysis the results are shown in Figure: 4. Green asterisks denote the calculated mean values of the measurements after the mean value of the dark current has been subtracted.

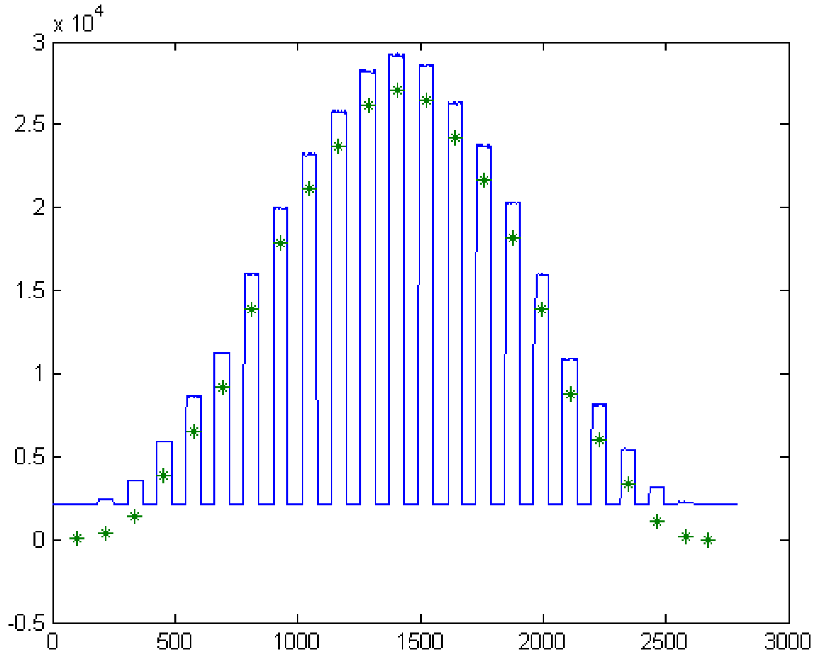

Figure 4: Mean values of measurement intervals of an angular response measurement after the pre-analysis

8 Evaluation of angular response results

During the NRPA campaign we had the chance to calculate some preliminary angular responses, in the 4 azimuth cross sections. One very interesting feature that we noticed in some of the instruments was a significant change in the intensity of the angular response measurements for a given channel for the 4 different azimuth positions. A difference up to 50% in extreme cases could be observed in the responses measured, regarding the maximum of the angular response curve at 0 degrees. In some of the instruments, however, this difference was very small, up to 5% (examples). The best behavior is observed in instruments with a relatively small diffuser, while those with a large diffuser show the greatest deviations from one angular response to the other. In Table I such results are presented for the angular response of the FMI NILU-UV instrument. For each channel, the maximum value at 0 degrees is found and all responses are normalized to this values to demonstrate the differences among the measurements even in the zero degree position for the four azimuths.

Table I: Angular response values at 0 degrees for the 4 different azimuths. For each channel the peak is normalized to the maximum value of all azimuths.

	Channel 1	**Channel 2**	**Channel 3**	**Channel 4**	**Channel 5**	**Channel 6**
North-South	1.0000	1.0000	0.6401	0.6264	0.9140	1.0000
NW-SE	0.9871	0.7723	0.6322	0.7834	1.0000	0.8235
West-East	0.9820	0.6694	0.7771	0.9483	0.9399	0.6661
SW-NE	0.9812	0.7408	1.0000	1.0000	0.7879	0.5915

This feature is an effect of the non-homogeneous illumination of the instrument diffusers in combination with the placement of the filters of each channel inside the instrument. The image of the arc lamp is much more luminous in some areas and much less in others. Even after the care taken to avoid the most luminous part (as described in paragraph 6), one cannot totally avoid this effect. As the instrument is placed in different azimuths and then rotated from –90 to 90 degrees, the relative position of the channel filters changes and this affect is more profound for large diffusers, since a diffuser with a small area would be even in this case more uniformly illuminated.

Tests could be performed to evaluate the way the diffusers are illuminated so that special care could be taken to ensure as homogenous illumination as possible. However it should noted that this is rather an artifact of the angular response characterization procedure. It is a matter that calibrators should attend to, but concerning the outside measurements of solar radiation by those instruments the effect is rather small, since the illumination by the sun is homogeneous.