Science Results From The Sova-Picard Total Solar Irradiance Instrument

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Abstract. The Picard satellite was successfully launched in a 6-18 orbit on 15 June 2010. The Sovap Total Solar Irradiance (TSI) instrument started its measurements on 21 July 2010. From July to October 2010 Sovap made low exposure measurements in its nominal operation mode, roughly once per month. On 18 October the operation mode was changed. The right channel has been opened permanently. For ageing verification additional left channel measurements are made monthly. For the different operation modes of Sova-Picard we present the relative TSI variation. For the determination of the absolute level of the TSI, we take into account the effect of heat losses for the electrical heating of the cavity, which has hitherto been neglected for the Differential Absolute RADiometer (DIARAD). We present some preliminary revised DIARAD TSI values, which need to be confirmed by further analysis and experiments.

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INTRODUCTION

Long-term monitoring of the Essential Climate Variable (ECV) Total Solar Irradiance (TSI) is important in order to understand the change of climate with time. Since the 1978, the TSI value and its temporal variation have been measured from space [1-9]. Recently, the disagreement of the Total Irradiance Monitor (launched in 2003) of the Laboratory for Atmospheric and Space Physics in Colorado [1] with the absolute level of other radiometers has been motivating scientists in the field to review their instrument precision.

The Solar Variability – Picard (Sovap) instrument is one of the two instruments measuring the TSI onboard of the Picard satellite. Sovap is a dual channel cavity radiometer with a left and right channel. Sovap is the sixth Differential Absolute Radiometer (Diarad) developed by the Royal Meteorological Institute of Belgium (RMIB), and it provides continuity for Diarad-Virgo on Soho which has been monitoring the TSI since 1996. In this article, the values for the Total Solar Irradiance measured by Sovap are reported. The reader is referred to reference [4] for details on the instrument design, qualification and performance.

INSTRUMENT OPERATION SUMMARY

Sovap-Diarad has a double differential design, allowing differential left-right and differential open-closed measurements. Depending on the left and right channel shutter operations, different operation modes exist that are described below. A more detailed description can be found in reference [4].

Nominal Right Channel Measurement – Auto 3

During the so-called 'Auto 3' mode, the left shutter is closed, and the right shutter sequentially opens and closes. The mode corresponds to the double differential operation. It has a sampling period of 3 minutes and an instrument noise level of 0.1 W/m². This mode has been used to measure the absolute level of the TSI and to verify the short term stability of the right channel. The mode has been used intermittently from 22 July 2010 until 28 August 2010. It had to be abandoned due to problems opening the right shutter.

Nominal Left Channel Measurement – Auto 2

During the so-called 'Auto 2' mode, the right shutter is closed, and the left shutter sequentially opens and closes. The mode corresponds to the double differential operation. It has a sampling period of 3 minutes and an instrument noise level of 0.1 W/m². This mode has been used to measure the absolute level of the TSI and to verify the short term stability of the right channel. The mode has been used intermittently from 28 August 2010 until 27 October 2010. The exposure time has deliberately been kept low at about 1 hour per month, in order to guarantee that the left channel was not ageing due to solar UV exposure.

Continuously Opened Right Channel Measurements – Rad 10

During the so-called 'Rad 10' mode, the right shutter is opened, and the left shutter is closed. This mode has been used since the permanent opening of the right shutter during the first occultation period on 17 November 2010. Compared to the nominal modes, this mode has the advantage of increased time resolution, but the disadvantage of decreased accuracy and stability since it only has the single differential left-right operation. The Sovap measurements are organized in packets of 90 s, consisting of 9 10 s measurements. In the routine Rad 10 measurements, the TSI is measured at seconds 20, 40, 70, 80 and 90 within the 90 s packet. In a dedicated Rad 10 high rate measurement mode, TSI measurements can be obtained every 10 s. The increased time resolution of the Rad 10 measurements is particularly useful for measuring p-mode irradiance variations without aliasing.

Left Channel Measurements With Opened Right Shutter – Auto 15

During the so-called 'Auto 15' mode, the right shutter is open, and the left shutter sequentially opens and closes. The mode corresponds to the double differential operation. It has a sampling period of 3 minutes and an instrument noise level of 0.1 W/m². As a continuity of the nominal left channel measurements up to 27 October 2010, this mode has been used from 10 August 2011 onwards. Again the exposure time has deliberately been kept low at about 1 hour per month, in order to guarantee that the left channel was not ageing due to solar UV exposure.

CAVITY EFFICIENCY

In order to improve the accuracy of the measured TSI values, the efficiency for the detection of the absorbed heat inside the cavity is revised. Past and present analyses of the cavity efficiency are based on the experimental determination of the local thermal efficiency. These experimental tests have been performed using a laser beam with wavelength 514 nm, and their setup and procedure are described on page 63 of reference [5]. The Sovap cylindrical cavity consists of a heat flux sensor covered with a heating resistor forming the bottom of the cavity, covered with black paint which also covers the side walls of the cavity, see figure 1-left. The radial distance r is measured from the center of the circular cavity bottom. Measurement results along the bottom of both Sovap cavities are shown in figure 1-right. The measurement points can be considered to represent local efficiencies by which locally dissipated heat is measured by the heat flux sensor.

Inside the cavity, the total amount of dissipated heat consists of two contributions, originating from (1) absorbed incoming solar radiation and (2) dissipation by the heating resistor that is positioned directly below the absorptive paint on the bottom of the cavity. Part (1) of the heat is considered to be detected with the local efficiency shown in figure 1 - rights. For part (2), one has always considered that the heat dissipated by the heating resistor was detected perfectly. However, it would be more correct to state that this electrical heat is detected with the same local efficiency as the optical heat. We assume that a local heating always has the same thermal effect, regardless whether this heating was obtained from an optical or from an electrical source. Therefore, a new correction factor is introduced in the TSI equation: the thermal efficiency parameter related to electrical effects. This parameter is defined as the ratio between the heat flux measured by the heat flux sensor and the dissipated electrical power, and we assume that this parameter can be calculated from the efficiency curve as the mean local efficiency over the area of the heating resistor.

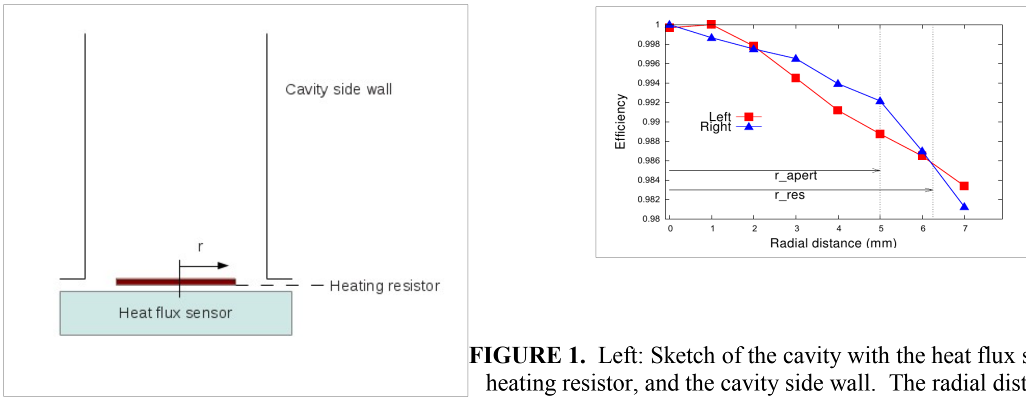

FIGURE 1. Left: Sketch of the cavity with the heat flux sensor, the heating resistor, and the cavity side wall. The radial distance r is measured from the center of the circular cavity bottom. Right : Relative surface efficiency as a function of the radial distance r for the left and right cavity of Sova-Picard. Each point is the average of six values, measured at different positions located along the same circle. Indicated on the graph are r_apert, the radius of the projected precision aperture, and r_res, the radius of the heating resistor. As a comparison, the radius of the cavities is 7.8 mm (rounded value).

FIRST SOVA-PICARD SCIENCE RESULTS

The currently available Sova-Picard TSI measurements are shown in figure 2. Separate absolute levels of the TSI are obtained for the instrument used in its differential open-close modes: right – Auto 3 in green, left – Auto 2 in red, and left – Auto 15 in purple. The absolute level of the continuously opened right – Rad 10 measurements in blue has been adjusted to the Auto 15 measurements, such that the Rad 10 measurements provide a time interpolation of the Auto 15 ones.

The Auto 2 – left channel and Auto3 – right channel modes are the nominal operation modes with a long history on the previous DIARAD type radiometers and with a detailed pre-flight characterisation, hence they are considered the most reliable ones.

Auto 15 – left channel is a new mode invented in-flight to cope with the problem of the right shutter opening. It lacks pre-flight characterisation and it uses a different electrical power level than the nominal ones. Therefore its TSI value is currently considered less reliable than the Auto 2 and Auto 3 ones.

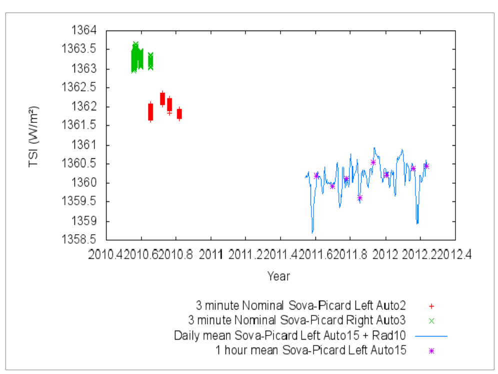

FIGURE 2. Sova-Picard Total Solar Irradiance measurements in different operation modes.

PRELIMINARY REVISION OF THE OLDER RMIB TSI MEASUREMENTS

Compared to our traditional method of TSI evaluation, for the Sova-Picard evaluation we have for the first time taken into account the hitherto neglected effect of thermal heat losses for the electrical heating of the Diarad cavities. This leads to a reduction of the absolute level of the Diarad type radiometer. Figure 3 shows the preliminary revision of the TSI levels of our older instruments taking into account this effect.

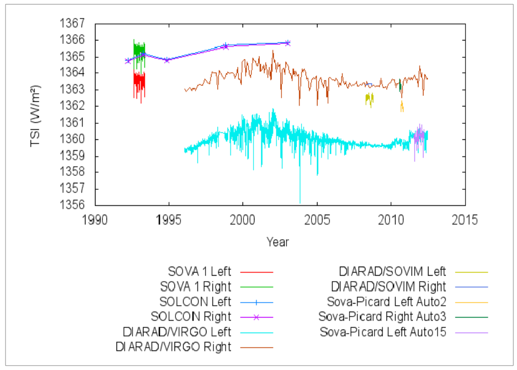

FIGURE 3. Individual RMIB TSI measurements after preliminary revision of the thermal efficiency. (figure in color)

FUTURE DIRECTIONS

We are part of the ISSI team of international TSI experts working together on the estimation of a new value of the solar constant. The revised Diarad TSI values presented in a preliminary way in this article, with the addition of further analysis, experiments and uncertainty estimates, will be our input to the ISSI team effort.

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