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Volume 17, The Seventh SeaWiFS Intercalibration Round-Robin Experiment (SIRREX-7), March 1999

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The summary statistic for the rotational effect on calibrations is formed from the maximum and minimum PCR values measured during the 360° rotation of the sensor, $\chi^{\max}_{S_{\mathrm{ID}}}(\lambda)$ and $\chi^{\min}_{S_{\mathrm{ID}}}(\lambda)$, respectively:

$$\chi^{\mathrm{rot}}_{S_{\mathrm{ID}}}(\lambda) = \frac{\chi^{\max}_{S_{\mathrm{ID}}}(\lambda) - \chi^{\min}_{S_{\mathrm{ID}}}(\lambda)}{2}. \tag{17}$$

The $\chi^{\mathrm{rot}}_{S_{\mathrm{ID}}}(\lambda)$ values for the rotation uncertainty experiment are given in Table 10. The P002 and X001 sensors have single apertures; the R035, R064, and I040 sensors are seven-channel instruments with a centermost channel (Fig. 3) which is usually the highest wavelength (except for R064). For the seven-channel instruments, the minimum rotation effect is associated with the center channel; this is particularly notable for R064 (a narrow FOV radiance sensor) and I040 (an irradiance sensor). The smallest average effect occurs for the single-aperture instruments.

Table 10. The results from the rotational experiments executed during SIRREX-7. The FAFOV of the radiometers is given in degrees and the centermost channel for the seven-channel sensors in bold. Averages for multi-aperture sensors were calculated without including the center-most channel.

λ [nm]	*R035* 20°	*R064* 6°	*P002* 17°	*X001* 2.4°	*I040* 180°
412	0.3	1.1	0.4	0.2	0.6
443	0.3	0.9	0.2	0.2	0.7
490	0.3	0.9	0.1	0.3	0.7
510	0.5	0.9	0.2		0.7
555	0.5	0.9	0.2	0.2	0.7
665	0.4	**0.1**	0.3	0.3	0.7
683	**0.3**		0.3		**0.2**
775			0.5	0.3	
780		0.8	0.5		
Average	*0.4*	*0.9*	*0.3*	*0.2*	*0.7*

The single-aperture sensors have similar average rotational effects, which are the lowest for the five sensors, but they are clearly different from a spectral point of view. The SXR rotational effect is spectrally flat, whereas, the hyperspectral instrument has maximal effects in the bluest and reddest wavelengths and minimal effects in the green domain.

7.3 POLARIZATION EFFECTS

The polarization sensitivity of radiance sensors during the calibration process involved three types of sensors: two OCR-200s (R035 and R064), an OCR-2000 (P002), and the SXR (X001). The OCR-200 has multiple apertures (arranged in a circular array), while the OCR-2000 and SXR have single apertures. The latter was also distinguished by being the only instrument with mirrors in the optical pathway (one for each channel).

7.3.1 Equipment

The equipment used for the radiance polarization trials was as follows:

- Satlantic Optronic lamp F-548 (L009);
- Satlantic white (18 in) plaque 05816 (T001), and JRC white (18 in) plaque 22463 (T004);
- OCR-200 R035 with DATA-100 (S/N 043);
- Monitor sensor, OCI-200 I121 with DATA-100 (S/N 047);
- OCR-2000 P002;
- The SXR (X001) with custom rotator mount and digital voltmeter (V003);
- Current source OL83A 99115110 (C001);
- Shunt resistor 1151570 (Z001);
- Voltmeter 3146A09840 (V002);
- Oriel rotator model 13059 equipped with a custom D-shaped collar adapter;
- Oriel stepper control box model 20010 (S/N 542);
- Rotator D-shaped collar adapter;
- Polarizing sheet (Melles Griot model 03–FPG–013);
- Polarizer mount adapter (Melles Griot model 07–HPA–011);
- Polarizer rotating mount (Melles Griot model 07–HPR–007); and
- Lamp mount, V-block and mount, plaque mount, seven carriers, alignment grid, and alignment laser 05–LHR–201–355.

7.3.2 Procedures

The DUT was placed on the 45° rail on calibration table 2 in the appropriate rotator mount. When the SXR was the DUT, a special mount was used to hold it to the rotator. All other radiometers were attached to the rotator using the D-shaped collar. The DUT was positioned on the rail such that the sensor was approximately 40 cm from the plaque along the rail axis, unless the DUT was the SXR, in which case the distance was set to 85 cm. A test was made to ensure the instrument could be rotated freely through 360° by driving the rotator through the full range of motion used in the experiment. Any wires were wound such that they did not hinder the circular movement or pull on the DUT.

The plaque (T001 or T004) was placed on the center rail in the proper carrier mount. A paper cover was placed over the active area of the plaque to protect it during all adjustments and to provide for proper boresight focusing of the SXR. The DUT was aligned with respect to the plaque using the alignment laser and the procedures given in Sect. 1.5.2. The alignment of the DUT was suboptimal, because it only had three degrees of freedom. It could be rotated around the post holding the rotator, it could

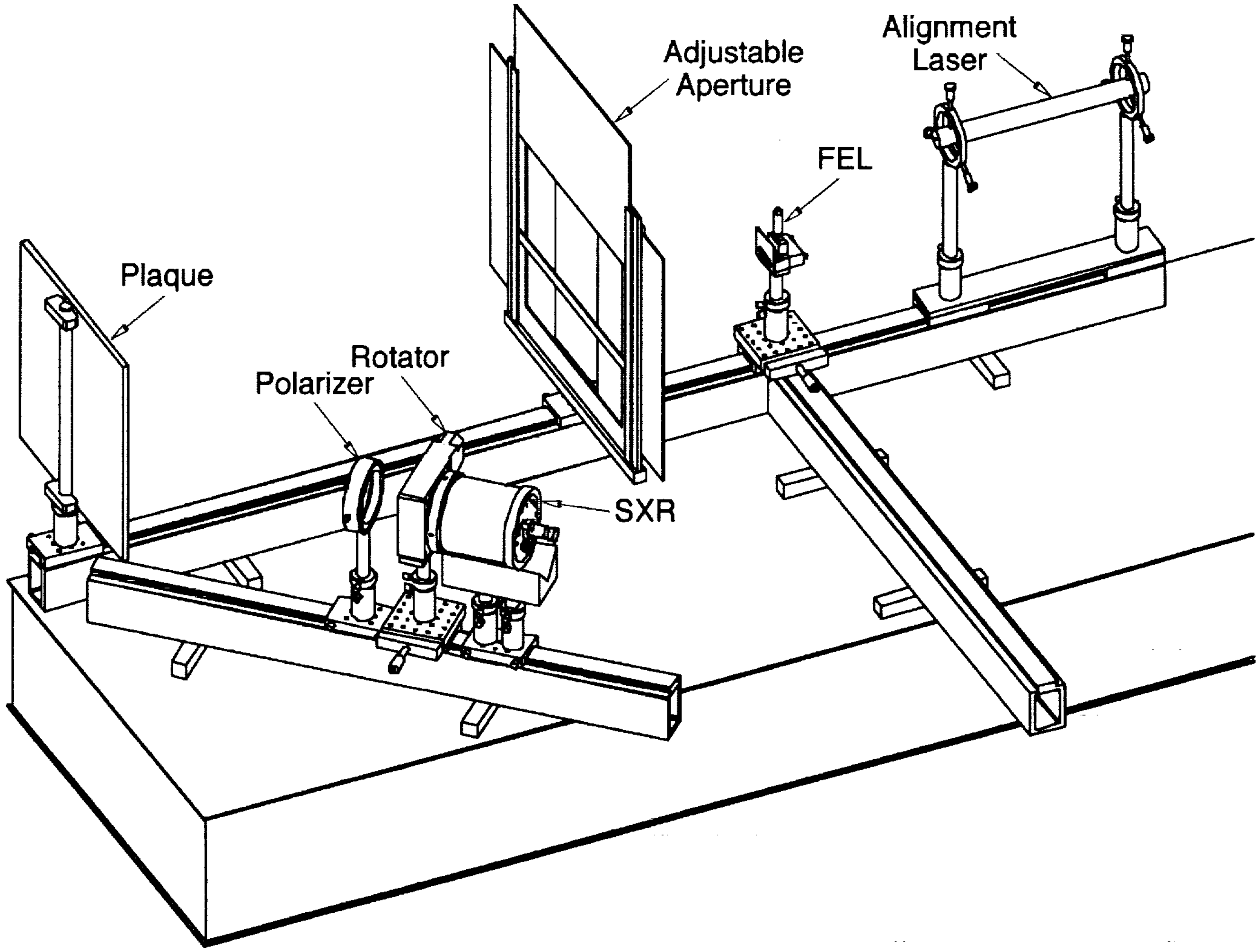

Fig. 29. The experimental setup for determining the polarization sensitivity of radiance sensors in radiance calibrations (in this case, with the SXR as the DUT). The adjustable aperture was opened or closed to ensure the plaque was completely illuminated, while making sure there were no shadows or diffraction edges on the plaque.

slide along the rail, and it could be raised and lowered. A translator was added to the carrier to allow it to travel orthogonal to the rail. This was necessary when using the SXR and the hyperspectral instrument (OCR-2000 P002) because they needed to rest on a V-block (due to their larger size).

Lamp F-548 (L009) was aligned and powered on following the procedures in Sect. 1.5.3. The aperture was adjusted so there were no shadows or diffraction edges on the plaque, and any stray light was minimized by following the practices given in Sect. 1.5.4. Figure 29 shows the experimental setup.

The first step in collecting data began with placing aperture caps on the DUT and the monitor sensor (I121), and then collecting dark data. If the SXR was the DUT, background data were collected immediately after the dark data. The next step was to record data every 2° over 360° without the polarizer. The polarizer was then placed immediately in front of the DUT and aligned following the procedures given in Sect. 1.5.2, after which, polarized data were recorded every 2° over a full 360° rotation of the sensor. During each measurement sequence, the monitor sensor provided a measure of the stability of the lamp flux over the course of the rotation sequence.

7.3.3 Results

The polarization parameter, P, for a particular radiance sensor (identified by the S_{ID} code) is defined in percent as

$$P_{S_{\mathrm{ID}}}(\lambda,\theta) = 100\,\frac{L_{S_{\mathrm{ID}}}^{\max}(\lambda,\theta) - L_{S_{\mathrm{ID}}}^{\min}(\lambda,\theta)}{L_{S_{\mathrm{ID}}}^{\max}(\lambda,\theta) + L_{S_{\mathrm{ID}}}^{\min}(\lambda,\theta)}, \qquad (18)$$

where $L_{S_{\mathrm{ID}}}^{\max}(\lambda,\theta)$ and $L_{S_{\mathrm{ID}}}^{\min}(\lambda,\theta)$ are the maximum and minimum radiances measured during the 360° rotation of the sensor, respectively.

The polarization parameters for four radiance sensors are presented in Table 11. Although all of the radiometers show a spectral dependence, they are not the same for each sensor type. The seven-channel sensors (R035 and R064) show maximal effects in the blue part of the spectrum which decrease towards the red domain, the hyperspectral instrument has minimal effects in the blue and maximal effects in the red, and the SXR exhibits only a mild spectral dependence with the largest effect in the bluest wavelength.

Table 11. The results from the polarization experiments executed during SIRREX-7. The center-most channels for the seven-channel sensors are shown in bold face.

λ [nm]	*R035*	*R064*	*P002*	*X001*
412	1.4	2.4	0.4	5.1
443	1.1	1.2	0.2	4.4
490	0.4	0.8	0.4	4.6
510	0.4	0.6	0.5	
555	0.5	0.9	0.7	4.5
665	0.5	**0.3**	1.5	4.3
683	**0.2**		2.0	
775			2.1	4.4
780		0.3	2.6	
Average	*0.6*	*0.9*	*1.2*	*4.6*

The smallest average polarization effect occurs for the seven-channel sensors, the hyperspectral instrument is a little larger, and the SXR is significantly larger. As was seen with the rotation experiments (Table 10), the centermost channel for the seven-channel sensors show the smallest effect, but as shown with the R064 sensor, part of this is associated with the spectral decrease from the blue towards the red domain.

The specification for polarization in the SeaWiFS Ocean Optics Protocols (Mueller and Austin 1995) is 2% or less. On average, all the Satlantic sensors are within this specification, although some individual wavelengths exceed this requirement. The SXR, in comparison, is always above 2%, with an average a little above 4.5%. In order to check whether or not the polarization values for the Satlantic above- and in-water OCR-200 sensors were typical, additional polarization experiments were conducted. The average polarization for the above-water sensor was 0.6%, and the average polarization for the in-water sensor was 0.9%. The average values are in close agreement to the SIRREX-7 values, but the values in the blue show the largest variability: the newest polarization values at 412 nm are 0.6% higher for the in-water sensor and 0.7% lower for the above-water sensor. This variability is also seen, in part, at 443 nm, so additional polarization experiments are probably needed to completely characterize this parameter.