NPOESS VIIRS Polarization Dependent Optical Crosstalk

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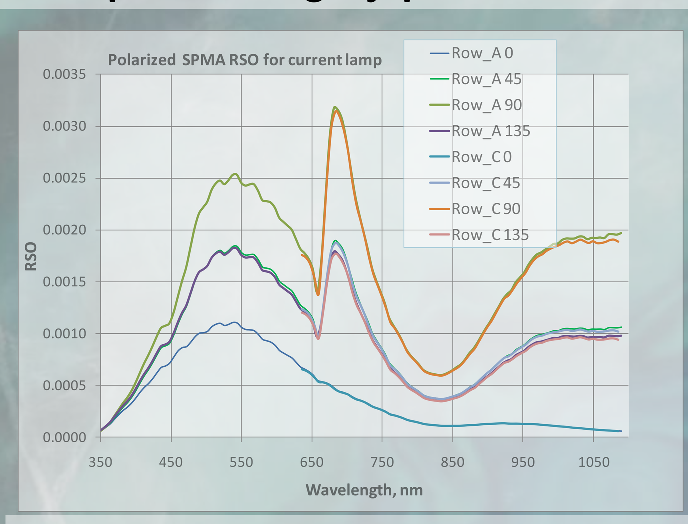
Introduction

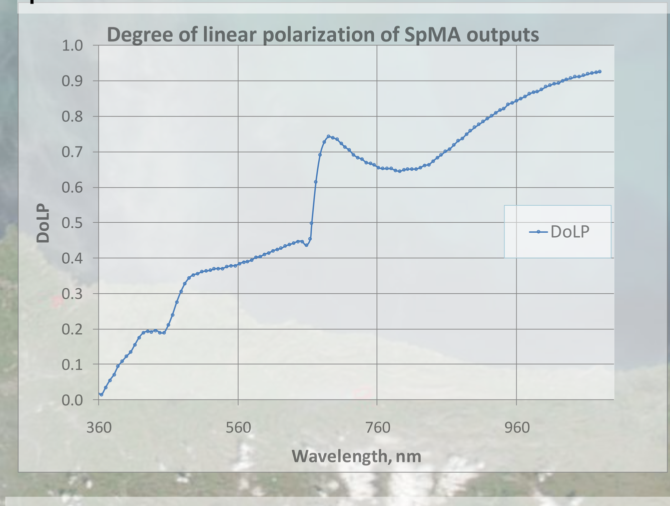
Knowledge of the relative spectral response (RSR) for each of the Visible Infrared Imager Radiometer Suite (VIIRS) band is essential for the algorithms to successfully retrieve the water-leaving radiance component and determine Ocean Color. The thermal vacuum tests for VIIRS Flight 1 sensor for the NPOESS Preparatory Project (NPP) included the RSR and optical crosstalk by viewing a highly polarized light source of a grating Spectral Measurement Assembly (SpMA). Since the visible and near infrared (VisNIR) bands of VIIRS on the Flight 1 are observed to have optical crosstalk that is sensitive to the polarization of incident light, it is possible for the RSR and crosstalk to be mischaracterized due to polarization of the test equipment. An RSR that describes only one polarization state of VIIRS may lead to errors in the Ocean Color Environmental Data Record (EDR) product. A polarization-independent "unpolarized RSR" is preferred to minimize such errors.

Supplemental tests were conducted to correct for the polarization in the SpMA source. Results of the supplemental test provided good correlation enabling extrapolation to wavelengths and bands beyond the test range. Analysis of the data has resulted in a prescription for correcting the SpMA polarization that is relatively mild. These observations suggest an effective RSR for the unpolarized light is applicable to mitigate the effects of the optical crosstalk in the VIIRS Flight 1 and the polarization of the Earth scene is likely to only exhibit a minor impact on the Ocean Color EDR. It is noted that the root cause of the optical crosstalk for Flight 1 has been corrected for Flight 2 and beyond.

The SpMA is highly polarized

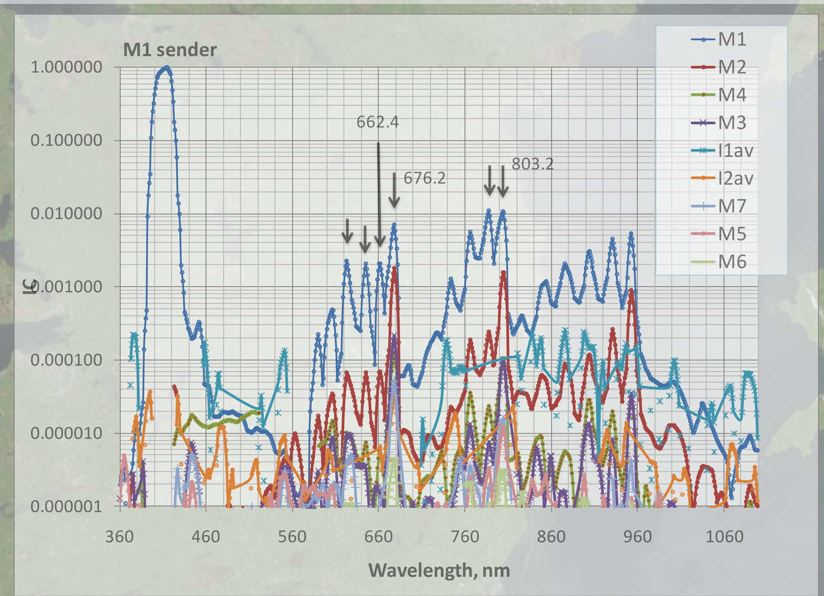


Polarization measurements with a wire-grid polarizer and NIST-traceable silicon photodiode (SiPD) show the "Woods Anomaly" feature of the source spectral output disappears entirely for some polarization states

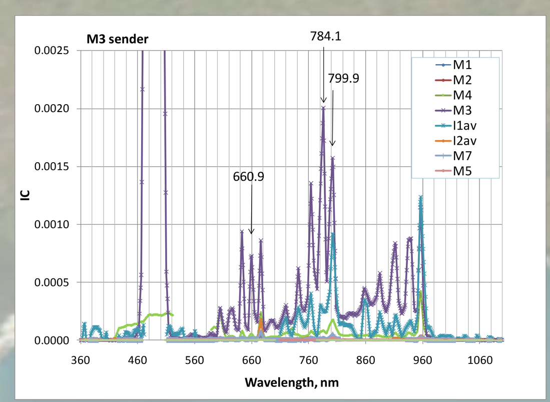


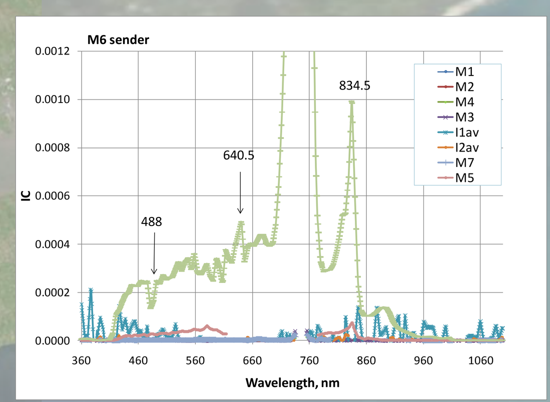
There is a high degree of polarization of the SpMA source that becomes more pronounced at longer wavelength.

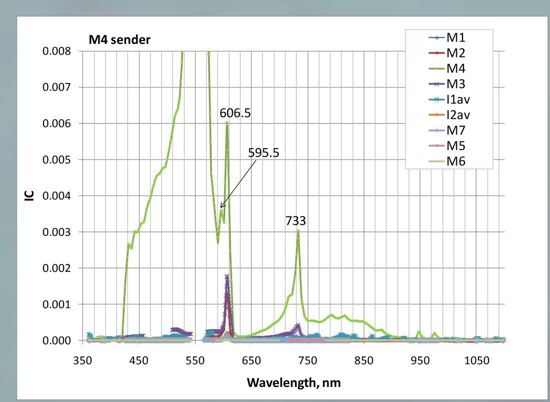
ETP-655 measures crosstalk polarization dependence at wavelengths where out-of-band signal is highest



Below, and at right, M3, M4, M6 crosstalk examples similar to the M1 example at left. ETP-655 polarization is measured at different "tall poles" than for M1.







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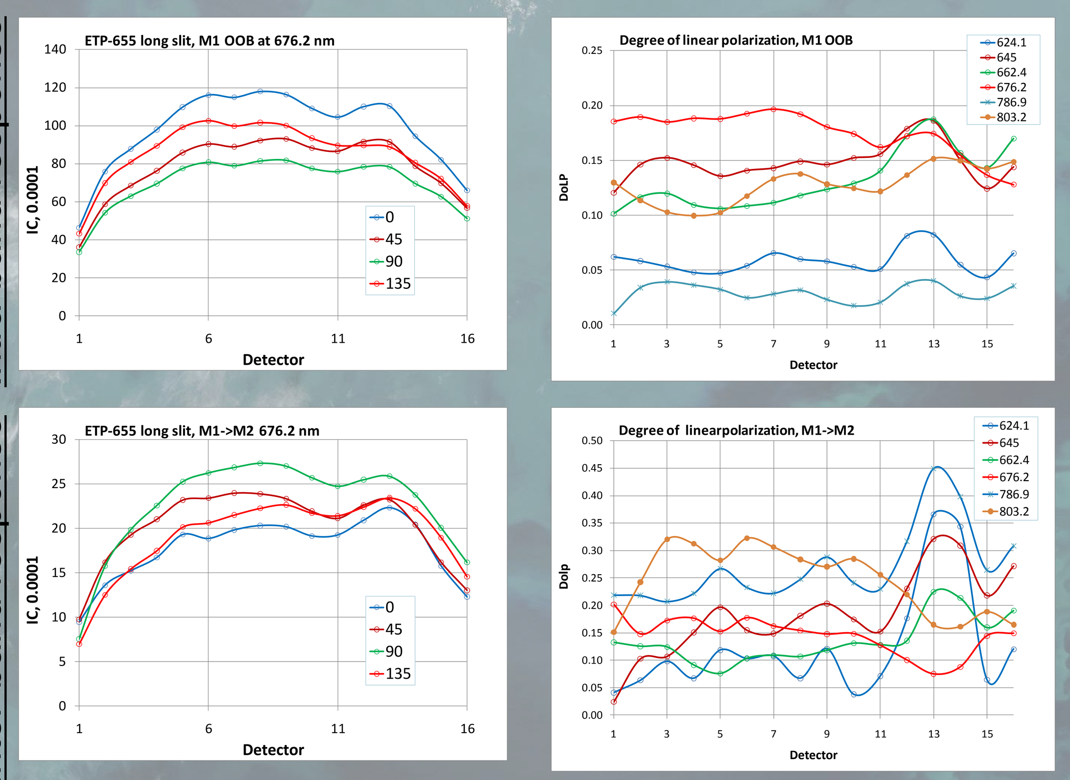
M1 Long-Slit Crosstalk Polarization at “tall-pole” wavelengths



← M1 to M1 intra-band response

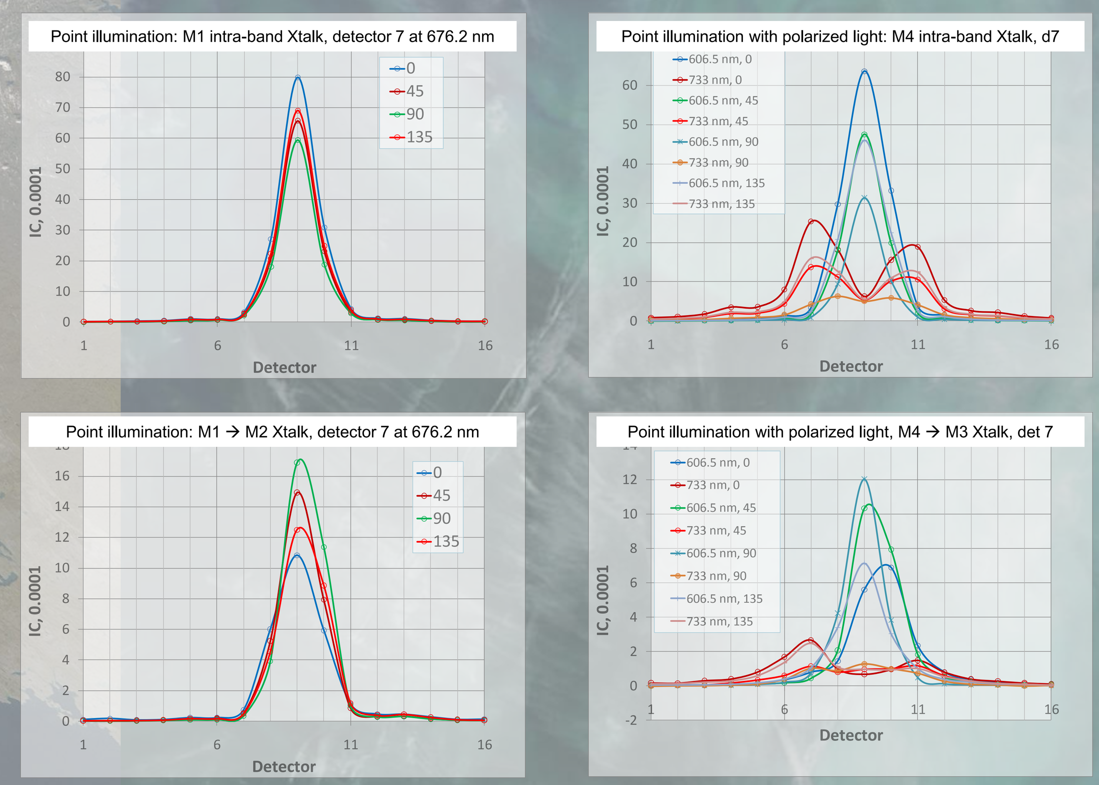
← M1 to M2 response

M1 at 676.2 nm over detector #

M1 degree of linear polarization at 676.2 nm over detector #

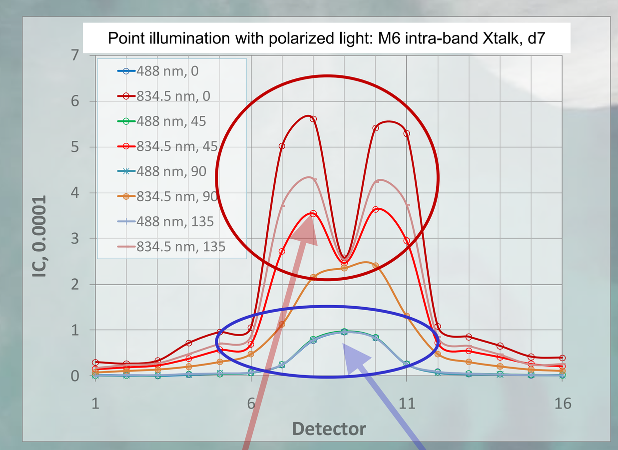
- 0º polarized light is favorable for intra-band crosstalk, 90º is favorable for inter-band crosstalk.
- Degree of linear polarization mostly less than 30% for M1 sender band.

Cross-slit Crosstalk Point Spread at “tall-pole” wavelengths



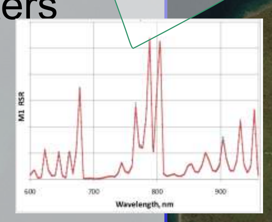
M1 detector 9 sender
M1 at 676.2 nm
M1 to M2 crosstalk
Polarization for Point Illumination Consistent with Slit Illumination

M4 detector 9 sender
M4 at 606 & 733 nm
M4 to M3 crosstalk



M6 detector 9 sender
Fluorescence peaks at 488 and 640.5 nm have no polarization dependence.
Wider spread function for crosstalk peak at 834.5-nm, which does have polarization dependence.
488nm and 834nm shown above.

Basis for Estimate of Crosstalk Polarization Parameters for Untested Peaks and Bands



- M1, M2, M3, I1 shows repeated bursts of several sharp peaks
  - Typical about 6 peaks with a similar IC ratio in a given burst
  - Good correlation of inter-band to intra-band IC ratio among the bursts
  - Good correlation of A2 and B2 values (or degree of polarization and phase angle) a derived from ETP-655 among the bursts
  - Suggesting **tall pole data in M1 and M3 can be used to estimate untested wavelengths**, and averaged values in M1 and M3 to estimate for untested M2 and I1
- Correlation of the spatial filter spread function (FSF) with filter orientation and of polarization with filter orientation
  - Wide FSF occurs only in blocker-up (toward light source) orientation
  - Narrow FSF occur in all blocker-down (toward detector) and those blocker-up at wavelengths closer to in-band
  - Suggesting **tall pole data in M4 and M6 can be used to estimate untested wavelengths for M4 to M7 and I2**
- Fluorescence peaks have no polarization dependence
  - **Applying all fluorescence peaks exclusively on the blue side of in-band for M4 to M7 and I2**

Equation to Correct for SpMA polarization

$$IC_{FP16} = IC_{unpolarized}(1 + DoLP_{SpMA} \bullet DoLP_{Xtalk} \bullet \cos 2(\alpha - \phi_{Xtalk} - \chi_{SpMA}))$$

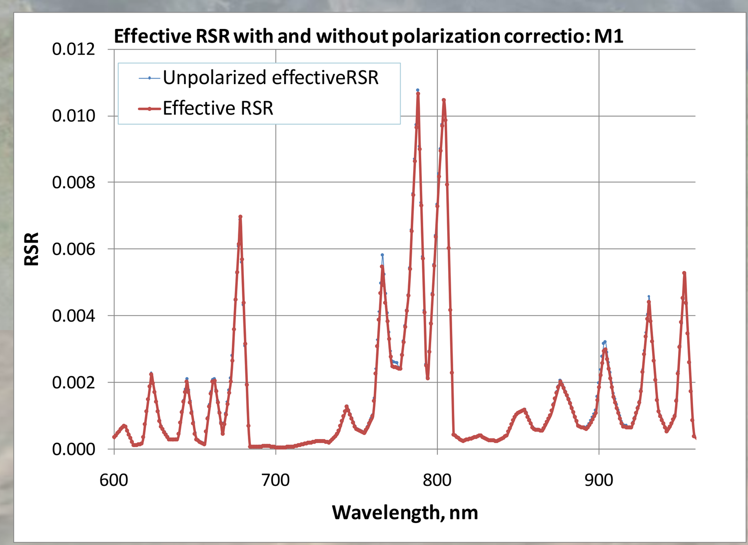
Here:

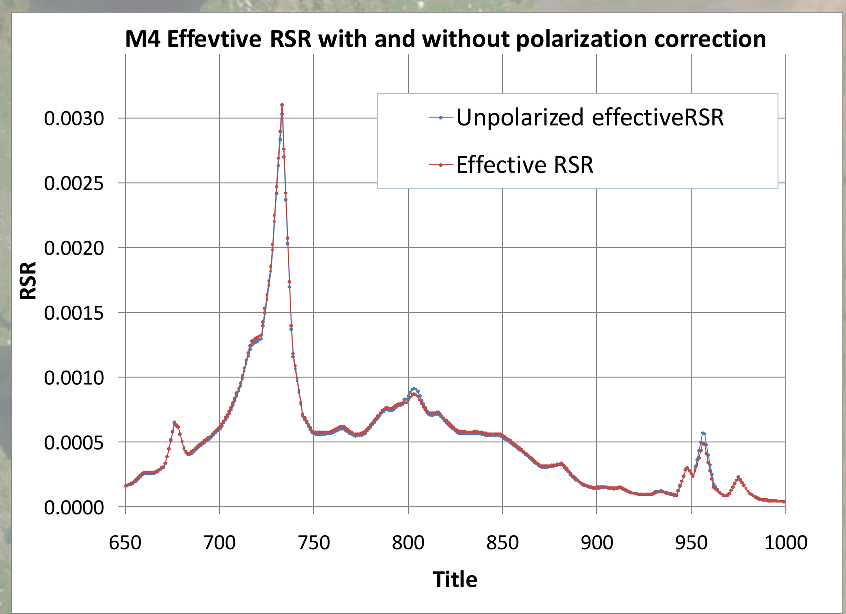
- IC_{FP-16}: Influence coefficient as measured in FP-16
- $IC_{unpolarized}$: Influence coefficient for unpolarized light
- Dop $_{SpMA}$: degree of polarization of SpMA outputs, derived from ETP-654
- χ_{SpMA} : Phase angle of SpMA outputs, derived from ETP-654
- $DoLP_{Xtalk}$: degree of polarization of crosstalk, derived from ETP-655
- φ_{Xtalk}: Phase angle of crosstalk, derived from ETP-655

- Influence coefficient as derived from FP-16 can be corrected for SpMA polarization using with DoLP of SpMA outputs and polarization parameters of crosstalk from ETP-655
- Correction can be applied to intra-band and inter-band crosstalk

Comparison of Effective RSR with and without Polarization Correction

M1 Correction appears to be relatively minor, attributed to relatively low DoLP (< 30%) for crosstalk polarization in M1, and cancellation of polarization because opposite intra-band. →

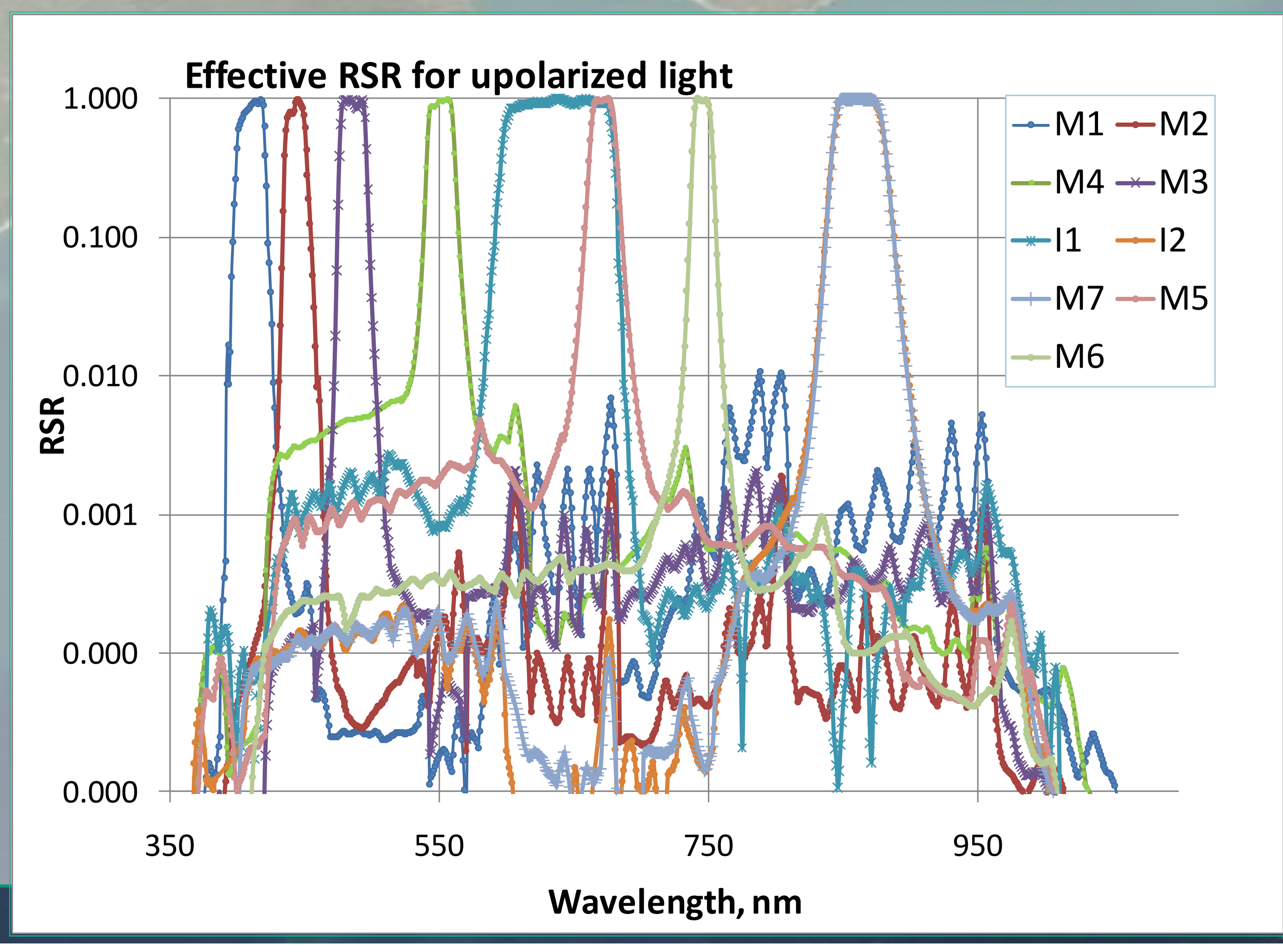




M4 correction appears to be minor though the degree of polarization is high (~55%). Attributed mainly to opposite phase angles between intra-band and inter-band crosstalk.. ↑

Detector Specific Effective RSR for Unpolarized Light: M1

RSRs are detector dependent, mainly within the in-band region. SpMA smile has been corrected. Residual dependence is in part due to telescope being non-telecentric.



Conclusion: Polarization has minor influence on Effective RSR

Effective RSR (as measured) is calculated by summing intra-band RSR/OOB with inter-band crosstalk from all sender bands per receiver detector and band. Effective RSR is corrected for SpMA polarization with derived crosstalk polarization parameters calculated from ETP-655.

Polarization correction appears to be mild. Unpolarized effective RSR will be used to generate LUTs for ACO, Aerosols and Surface Reflectance for crosstalk mitigation.