Assessment of J1 VIIRS Polarization Sensitivity Impacts on Sensor Data Records

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1. Introduction

Prelaunch polarization characterization indicates that the polarization sensitivity in bands M1-M4 of the Visible and Infrared Imaging Radiometer Suite (VIIRS) onboard the Joint Polar Satellite System–1 (JPSS-1, J1) is higher than the performance specifications. It is important to understand its impacts on the sensor data records (SDR) for reliable environment data records (EDR) retrieval, such as ocean color products. This study focuses on assessments of the impacts of J1 VIIRS polarization sensitivity on band M1 (0.411µm) in which the degree of linear polarization (DoLP) due to Rayleigh scattering and instrument polarization sensitivity are more profound than other bands.

In this study, Suomi NPP VIIRS band M1 polarization components for the Rayleigh scattering were modeled using the Second Simulation of a Satellite Signal in the Solar Spectrum Vector Code, version 1.1 (6SV). Polarization characteristics as functions of solar illumination and sensor view geometry were first studied. Then we adopts a MODIS polarization correction method proposed by Meister et al. (2005) to investigate the impact of linear polarization on J1 VIIRS band M1 TOA reflectance. J1 VIIRS was assumed to have the same along track and along scan patterns and local equator crossing time as that of the NPP VIIRS. Clear-sky Stokes vectors for the Rayleigh component were simulated using 6SV for a representative NPP VIIRS orbit over the Pacific Ocean. J1 VIIRS prelaunch polarization sensitivity data, including polarization amplitude and phase angle for each band, HAM-side, detector, and scan angle, were obtained from the NASA VIIRS Calibration Support Team.

2. 6SV Simulation of VIIRS band M1 Polarization over Ocean

- Satellite observations over clear-sky ocean at large sensor view zenith angles (VZA) are dominated by Rayleigh (molecular) scattering in the visible spectrum (Fig.1).
- The degree of polarization in TOA reflectance over ocean is dominated by the degree of linear polarization (DoLP) of the Rayleigh component. Contributions from circular polarization, aerosol scattering, and surface are small.
- Polarization components (Stokes vector: I, Q, and U) of Rayleigh scattering were simulated using 6SV for NPP VIIRS M1 observations over the Pacific Ocean (April 17, 2014, orbit 12806, see Fig.2). DoLP was estimated using Eq. (1) and plotted in Fig.3.

$$DoLP = \frac{\sqrt{Q^2 + U^2}}{I} \quad \text{(Eq. 1)}$$

- DoLP in TOA radiance/reflectance varies strongly with VZA, solar zenith angle (SZA), and relative azimuth angle (RAA) , typically from 0 to 70% (see Fig. 4 and 5).

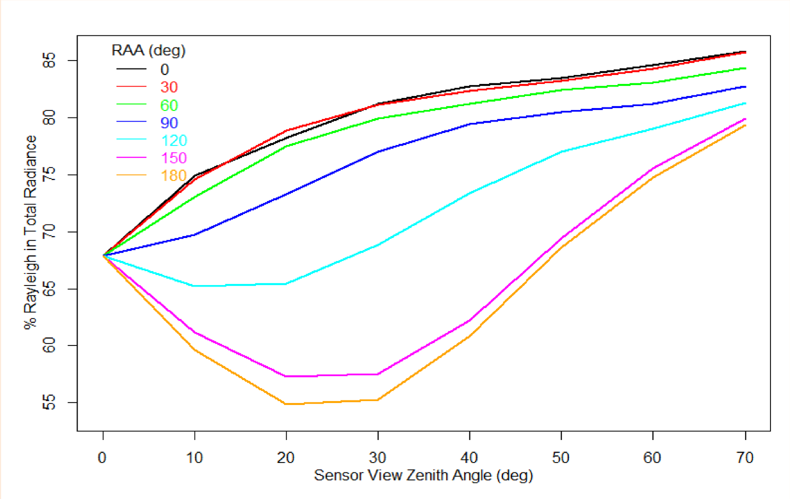

Fig.1 6SV simulated percentage of Rayleigh scattering in band M1 total TOA radiance as functions of VZA and RAA (at SZA=20°, wind speed=10 m/s, and wind direction=60°).

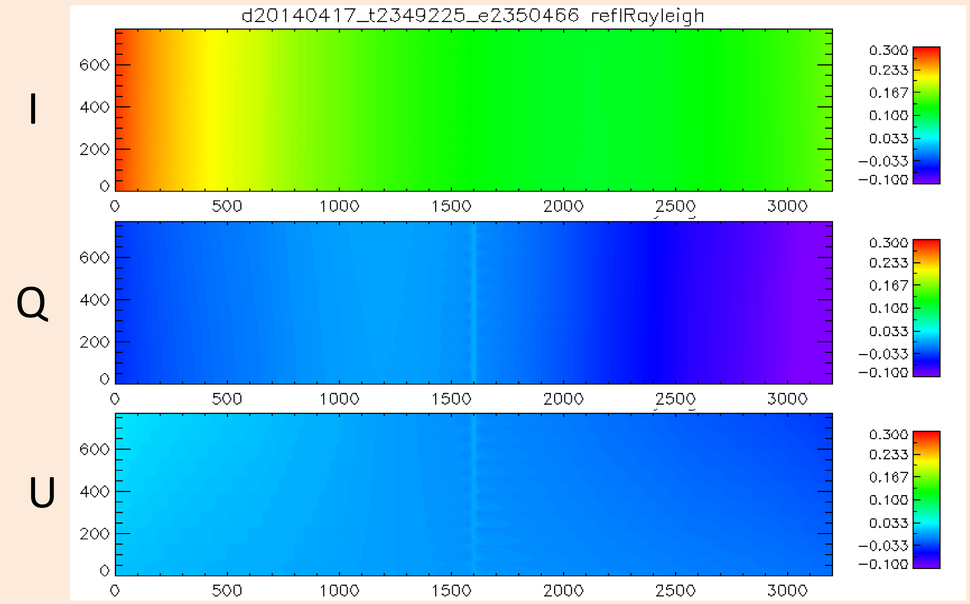

Fig.2 6SV Simulated Stokes vector of Rayleigh scattering for a NPP VIIRS band M1 granule on April 17, 2014 over MOBY Hawaii.

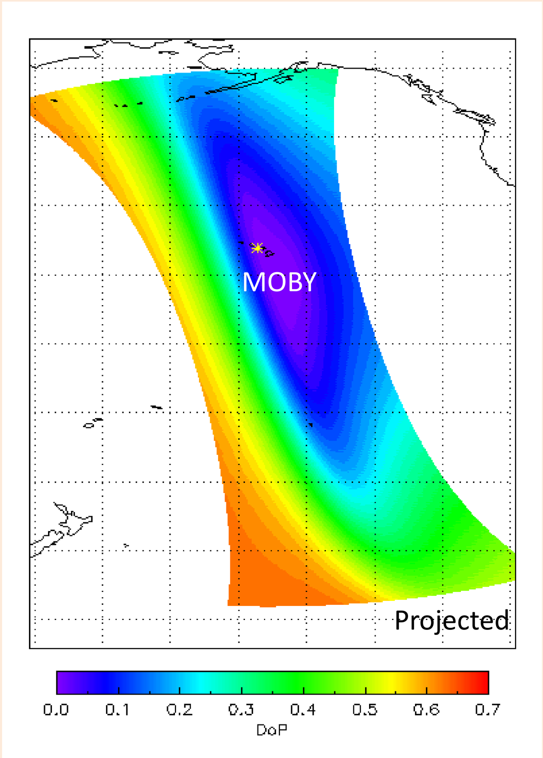

Fig.3 Band M1 DoLP derived from 6SV simulated Stokes vector for a NPP VIIRS orbit over the Pacific Ocean on April 17, 2014

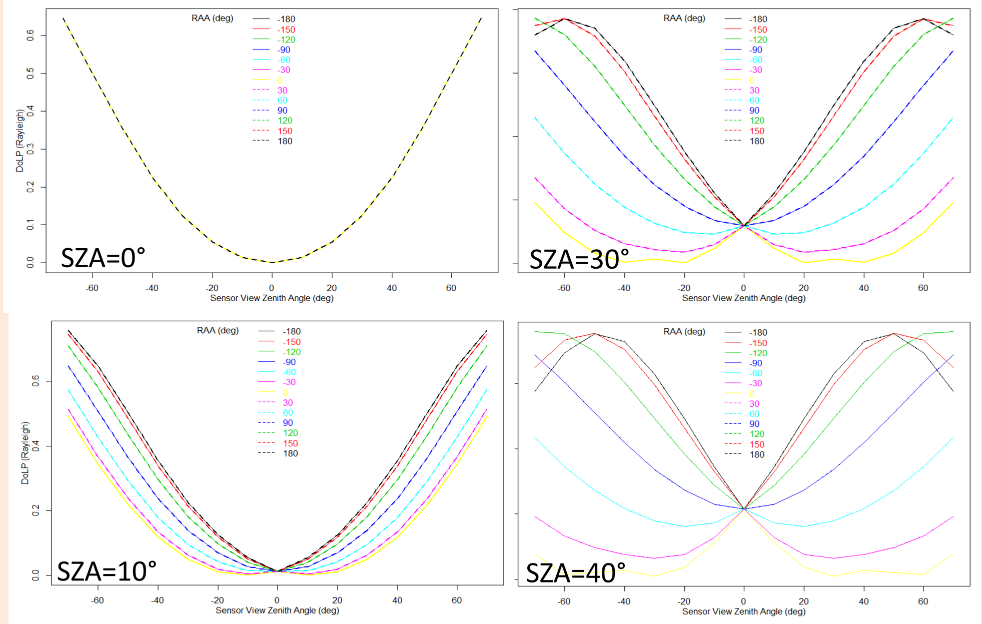

Fig.5 6SV simulated DoLP in the VIIRS band M1 TOA reflectance functions of VZA, SZA, and RAA.

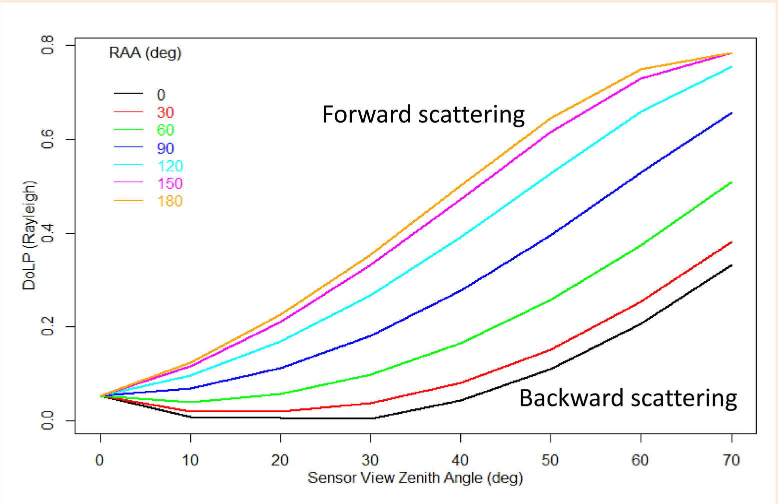

Fig.4 Same as Fig.1, but for DoLP. Stronger DoLP is observed at larger VZAs in the forward scattering direction.

3. Impact of J1 VIIRS Polarization Sensitivity on SDR

- **Polarization correction algorithm** (Meister et al. 2005)

$$I_m = I_t + m_{12}(Q_t \cos2\alpha + U_t \sin2\alpha) + m_{13}(-Q_t \sin2\alpha + U_t \cos2\alpha) \quad \text{(Eq. 2)}$$

I_m : Measured TOA reflectance
I_t : TOA expected reflectance ('truth')
Q_t, U_t : linear Stokes vector components
α : angle between incident light and sensor reference plane
m_{12}, m_{13} : fitted instrument characterization parameters

- **J1 prelaunch polarization data provided by VCST,** including polarization magnitude (*pm*) and phase angles (*pp*), per detector, HAM side, and scan angle.
  The response of band M1 varies by as much as 6% for completely polarized light.

- **α = 0 for prelaunch measurements, Eq. (2) can be simplified as:**

$$I_m = I_t + m_{12}Q_t + m_{13}U_t \quad \text{(Eq. 3)}$$
$$m_{12} = -pm\cos(2{*}pp)$$
$$m_{13} = pm\sin(2{*}pp)$$

- **Impact of polarization**

$$Impact(\%) = (I_m - I_t)/I_t{*}100 \quad \text{(Eq. 4)}$$

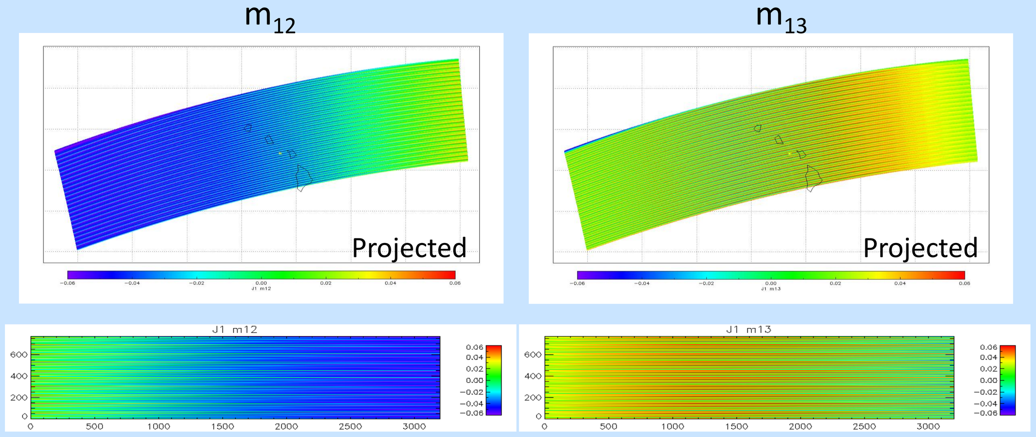

Fig.6 m_{12} & m_{13} estimated using J1 prelaunch polarization data for the same NPP VIIRS granule as Fig.2.

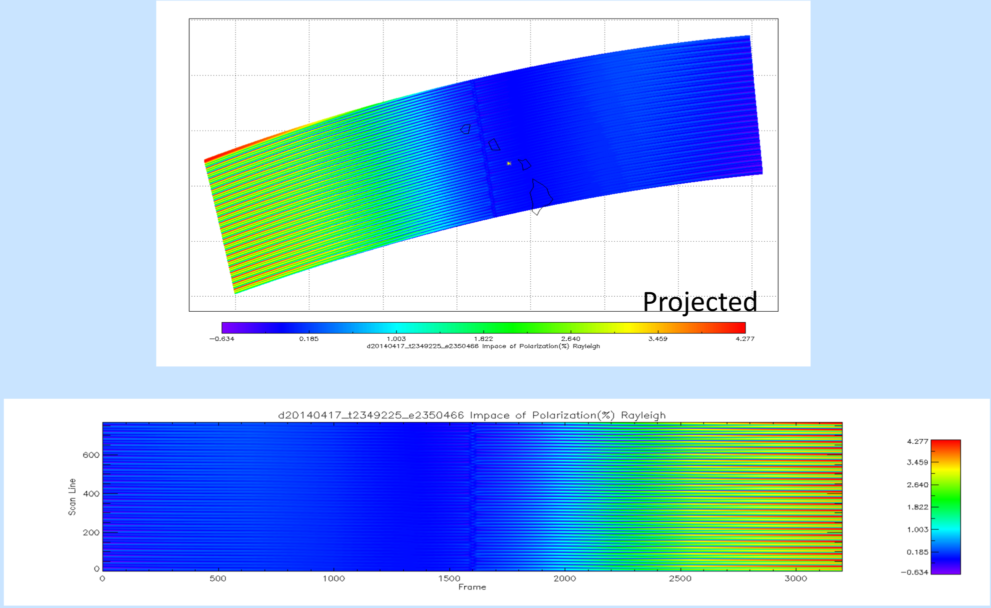

Fig.7 Impact of polarization on band M1 TOA reflectance for the same NPP VIIRS granule as Fig.2. The maximum impact is ~4%.

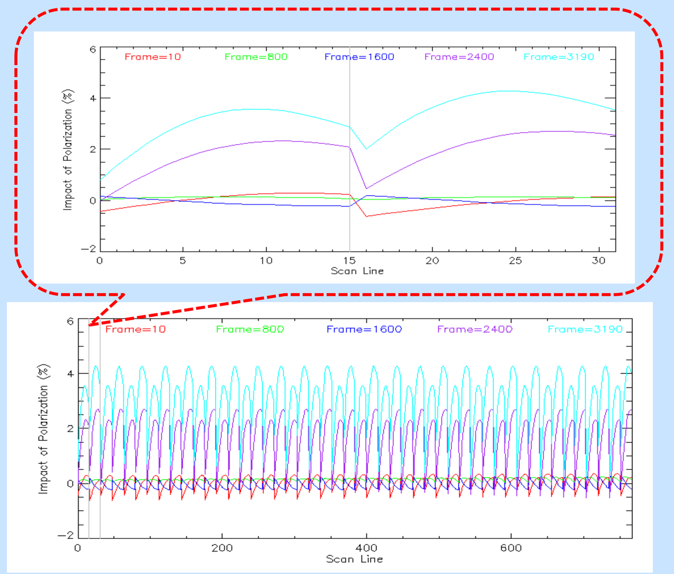

Fig.8 Profiles of the impact of linear polarization on a band M1 TOA reflectance for 3 typical frames. Stripping on the order of ~4% is clearly observable. The stripping is due to detector level polarization amplitude and phase differences.

4. Summary and Future Work

- **VIIRS band M1 linear polarization over ocean was modeled using 6SV, stronger DoLP is observed at larger VZAs in the forward scattering direction**
- **The Impact of linear polarization on J1 VIIRS band M1 SDR was estimated over a typical NPP VIIRS ocean granule. Assuming J1 and NPP VIIRS has the same along track and along scan patterns and local equator crossing time, J1 VIIRS polarization sensitivity can cause:**
  1. as much as ~4% of errors in band M1 SDR (compared to a ideal instrument without polarization sensitivity);
  2. as much as ~4% of striping in band M1 SDR due to differences in detector level polarization amplitude and phase angle.
- **Next step:**
  1. Investigating the impacts of J1 polarization sensitivity on bands M2-M4;
  2. Comparing the impacts of polarization sensitivity on NPP and J1 VIIRS bands M1-M4 SDRs.

References

1. Cao et al., 2014, Early on-orbit performance of the Visible Infrared Imaging Radiometer Suite onboard the Suomi National Polar-Orbiting Partnership (S-NPP) satellite, *Geoscience and Remote Sensing, IEEE Transactions on*, 52(2), p1142 – 1156.
2. Cao et al., 2013, Suomi NPP VIIRS sensor data record verification, validation, and long-term performance monitoring, *Journal of Geophysical Research: Atmospheres*, 118(20), p11,664–11,678.
3. Schott, J. R., 2009, Fundamentals of polarimetric remote sensing, *SPIE PRES*.
4. Meister et al., 2005, Moderate-Resolution Imaging Spectroradiometer ocean color polarization correction, *Applied Optics, 44(26), 5524-5535*.