The Emergence of Non-Principal Meridian Neutral Points in Maritime Polarized Light Fields

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Rayleigh single-scattering predicts neutral points (locations where the polarization vanishes) in the solar and anti-solar directions. Higher-order scattering is predominately a depolarizing mechanism, but it cannot further depolarize light when its degree of polarization is already zero. Instead, it serves to introduce a partially polarized component that alters the location of the neutral points. These locations, in addition to the overall degree of polarization, are useful metrics in describing the polarized distribution of light and its formation under multiple scattering.

In this work, an in-water polarimeter, PixPol, was used to measure the downwelling and upwelling spectral polarized radiance distributions just above and below the sea surface, respectively. PixPol's measurements were compared with Monte Carlo model simulations of the coupled atmosphere-ocean system. The model had the capability to disassociate photon paths by the interactions that occur, and so illustrate the different polarization features introduced by different components of the system. As part of the optical closure assessment, the modeling used Mueller matrices for water column scattering derived from measurements made concurrently with the MASCOT instrument and, for comparison, the published Voss and Fry (1984) averaged ocean-water Mueller matrix.

There was good closure in the overall pattern of polarization between measurements and the model, especially for the downwelling radiances. However, differentiation between modeled upwelling results when using Voss and Fry or MASCOT Mueller matrices was subtle, and the measured degree of linear polarization was systematically slightly lower in blue and green wavelengths. Modeling and measurements both supported the emergence of non-principal meridian neutral points in the downwelling skylight, comparable to those last observed by Soret (1888) and show they arise due to the component of light reflected from the sea surface and subsequently scattered downward. Additionally, the results indicate the conditions necessary for in-water neutral points in the upwelling radiance to occur off the principal meridian. Here, the diffuse skylight field plays an essential role, but their occurrence is also extremely sensitive to instrument self-shading. Even a tiny reduction of the direct path increases the likelihood of their experimental observation, which may provide some insight into the measurements by Voss et al. (2011) where these off-axis neutral points were not replicated by their modeling. Our results can be used to help interpret polarized water-leaving radiance distributions now measured by the SPEXone and HARP2 polarimeters for the PACE mission and guide future closure experiments.

References

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