Effect of microplastics on the polarization of the sunglint signal

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The Fresnel laws of specular reflection determine **glint polarization**. Radiative transfer simulations at the TOA, with the ocean reflectance modified to account for different fractions of **floating microplastics**, are inverted to retrieve the **ocean surface refractive index** and reveal anomalies from pure seawater.

Motivation

The Fresnel laws of specular reflection directly connect remote sensing observations of light polarization within the sunglint region to the refractive index of the ocean surface. The retrieval technique has been previously demonstrated to effectively reveal anomalies associated with the presence of substances that "replace" the air/water interface with a well-formed film, such as oil slicks. There is obvious interest in testing whether such a technique can be extended as far as detecting the presence of floating microplastics, for their ubiquity and societal relevance.

An advanced, vector radiative transfer code was used to simulate spaceborne observations where the ocean reflectance is modified by variable area fractions of floating microplastics, and for different scattering geometries and environmental conditions. The reflectance spectra of plastics originate from real laboratory measurements. The simulations are then inverted to retrieve the *effective* refractive index of the ocean surface under different assumptions on the knowledge of the aerosol properties.

Conclusions

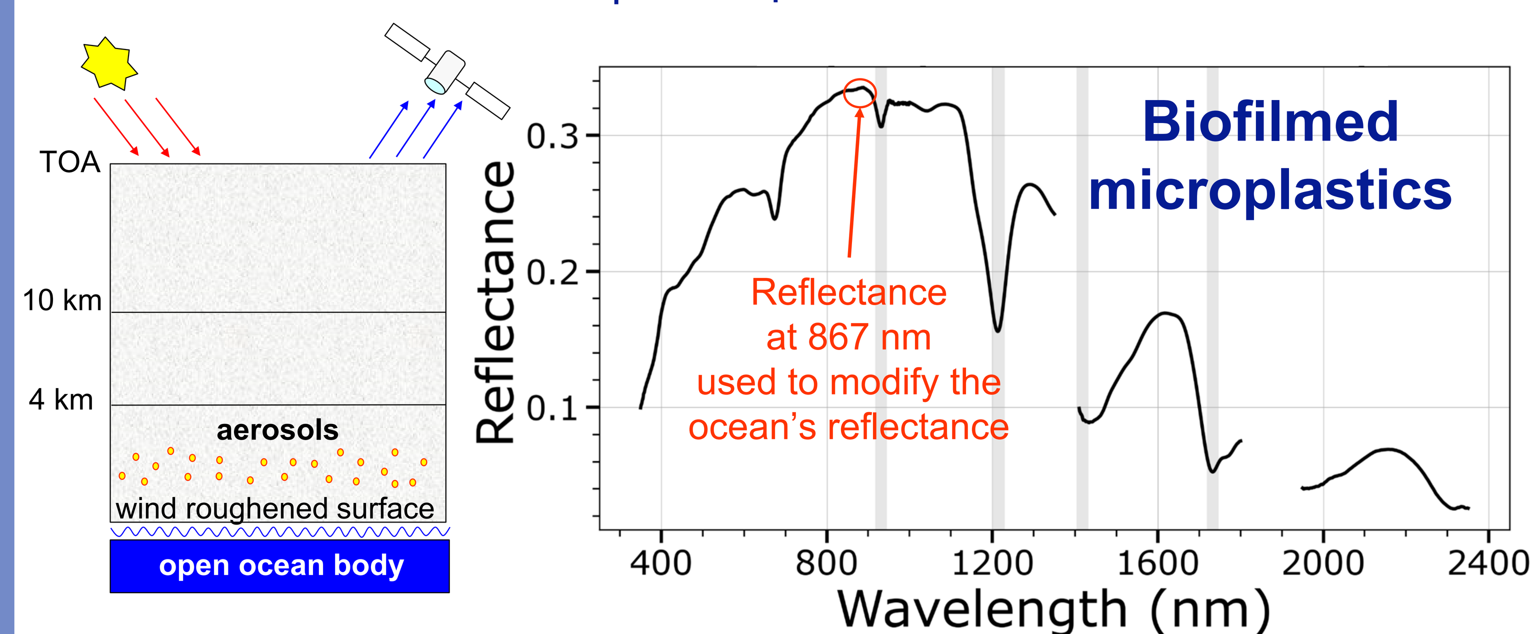
For well-formed floating slicks (e.g., oil) the ocean surface refractive index can be retrieved by inverting intensity and polarization measurements in the glint region.

Modifying the ocean reflectance top account for the presence of microplastics (modeled as Lambertian reflectors) diminishes the effectiveness of the glint retrieval technique because microplastics do not reflect specularly and are less polarizing than water surfaces.

Anomalous retrievals of surface refractive index become evident when the fraction of the surface covered by microplastics is larger than ~1%.

Methods

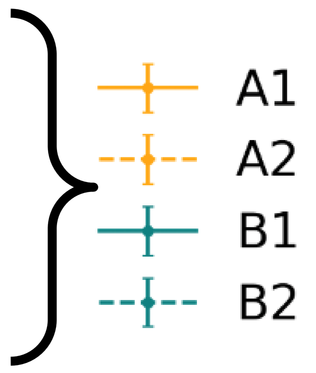
The upwelling Stokes parameters (I, Q, U) at the top of the atmosphere are simulated at 867 nm for a rough ocean surface containing different concentrations of floating microplastics. The reflectances are then inverted for the **ocean surface refractive index** using a Python implementation of a least-squares optimization scheme.



Constants:
Wind speed=5 m/s, Azimuth=0° (principal plane), AOT(870)=0.04.

Assumptions during the inversion:
A) AOT=0.04 (equal to that of the forward simulation)
B) AOT is retrieved simultaneously with the refractive index

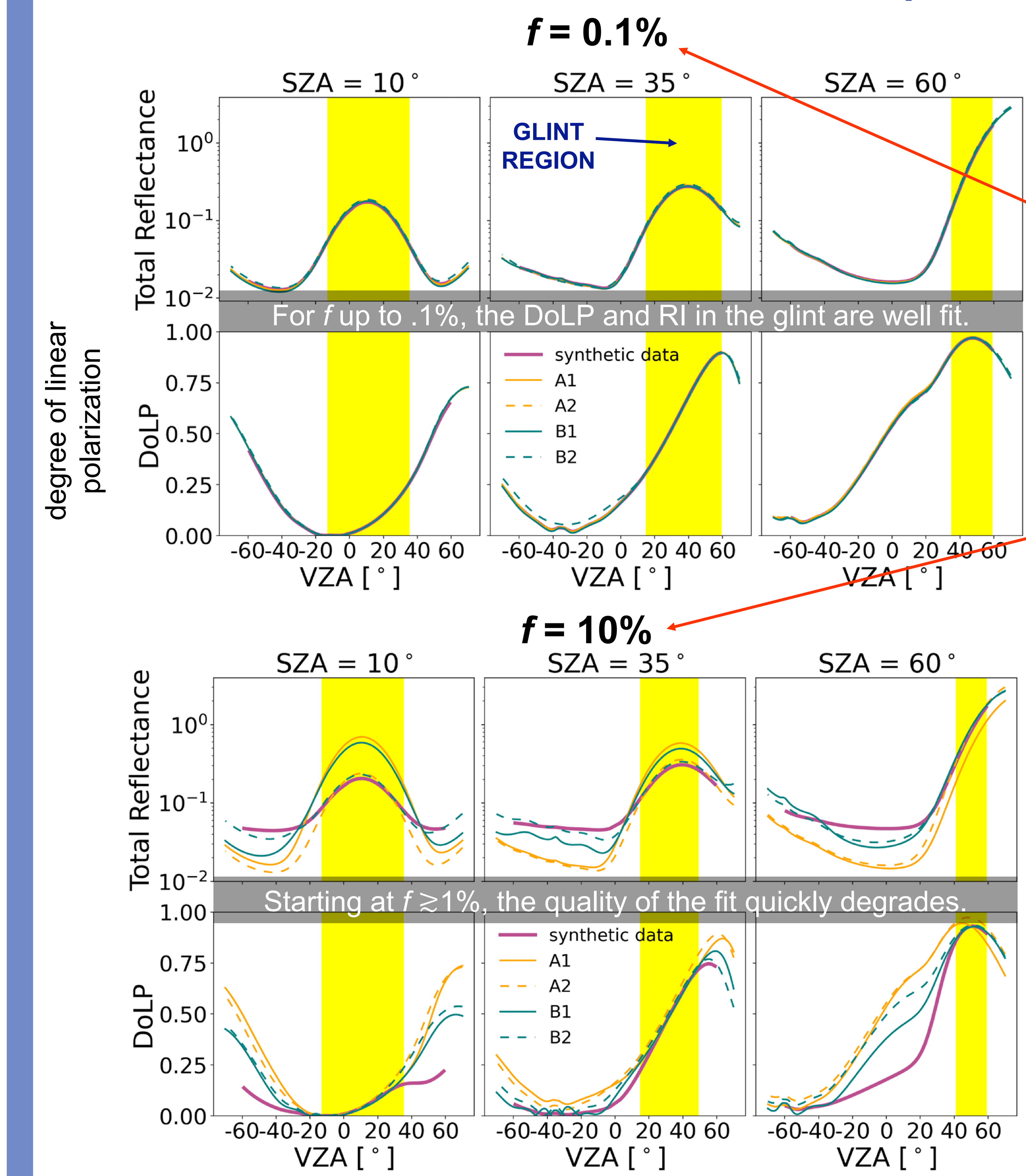
Measurement vector (along the principal plane of reflection):
1) Degree of linear polarization (DoLP) in the glint region
2) DoLP in the glint region + total reflectance at all angles



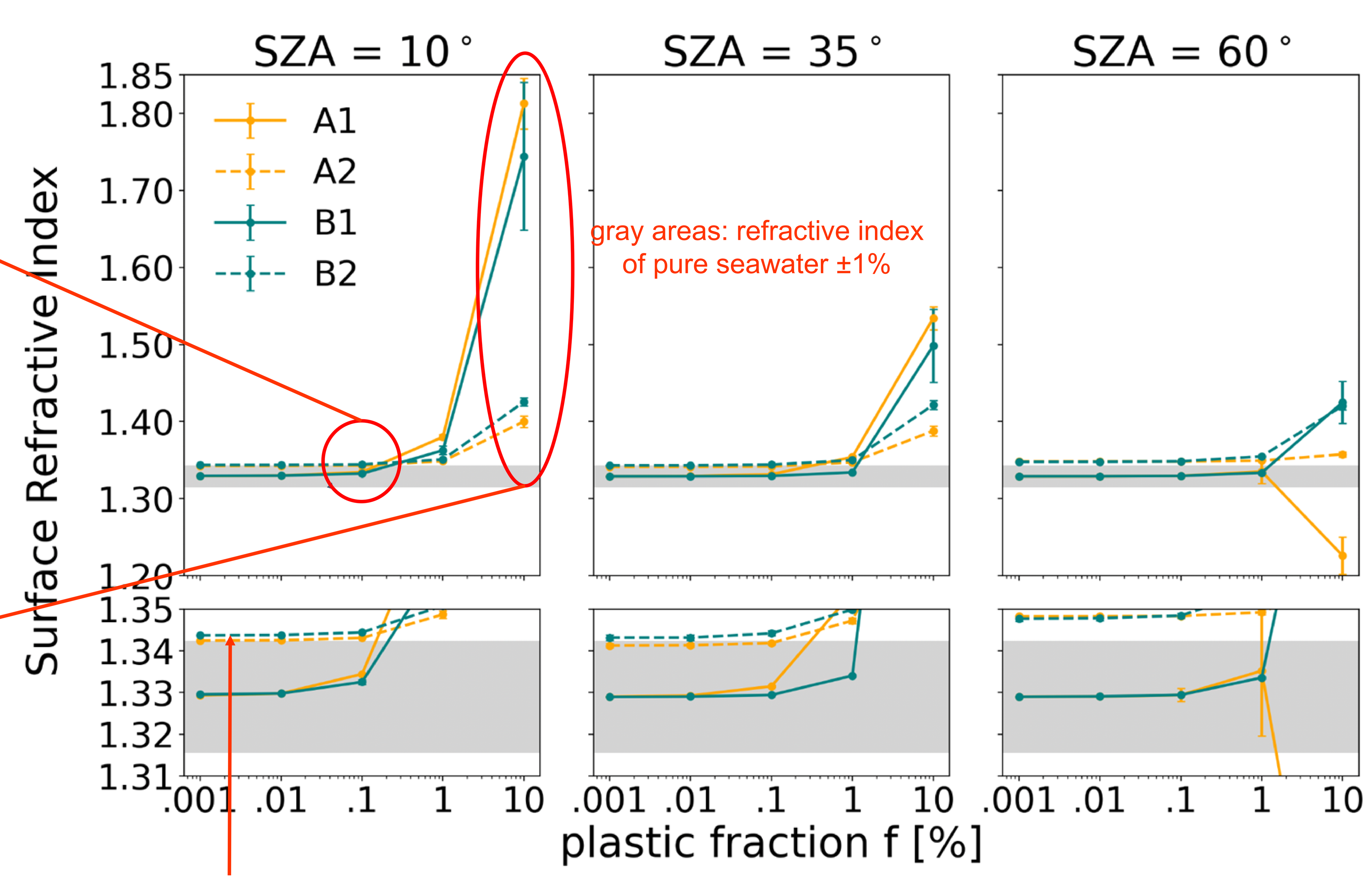
The refractive index is retrieved for different area fractions *f* of floating plastics (*f* = .001%, .01%, .1%, 1%, 10%) and solar zenith angles (10°, 35°, 60°), and for each combination of the assumptions above.

Results

Inversion results under different assumptions:



Summary of all inversions for all fractions



Inversions that include total reflectance at all angles (A2 and B2) to retrieve AOT show anomalous refractive indices already at small fractions dependent on minute differences between the different RT models used for the forward and inverse computations.

When the fraction of plastic covering the ocean surface exceeds ~1%, discrepancies in the fits become apparent and lead to larger error bars for the retrieved refractive index. These discrepancies arise because microplastics do not reflect specularly (unlike seawater or slicks) as assumed in the inversion.

Microplastics can be differentiated from normal seawater and other floating slicks (e.g., oil) by flagging retrievals that deviate from the refractive index of seawater (e.g., with Chi-Square/RMSE tests or thresholding the error bars).