National Aeronautics and Space Administration

FY25 Strategic University Research Partnership (SURP)

Quantifying potential of JPL's MAIA missions for atmospheric microplastics characterization

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Objectives:

The main goal of this study was to quantify the potential of the Multi-Angle Imager for Aerosols (MAIA) instrument for sensing and retrieval of atmospheric micro- and nano-sized plastics, from here on out denoted as atmospheric microplastics (AMPs), with objectives of

1) Determining the size and particle shape distributions of AMPs through optical characterization of dry and wet deposition samples collected at a field site in West Lafayette, Indiana;
2) Conducting a thorough literature review for wavelength dependent refractive indices of relevant AMPs and particles size distributions for AMPs with a focus on MAIA wavelengths and particle size sensitivity;
3) Characterizing scattering and polarization properties and signatures of natural aerosols (dust) and AMPs through use of the GRASP spheroid model.

To date there are limited policies in place, both nationally and globally, focused on limiting exposure to plastics and big questions remain regarding human exposure to AMPs, such as their spatio-temporal distribution in the atmosphere, atmospheric transport and deposition processes, and atmospheric processing.

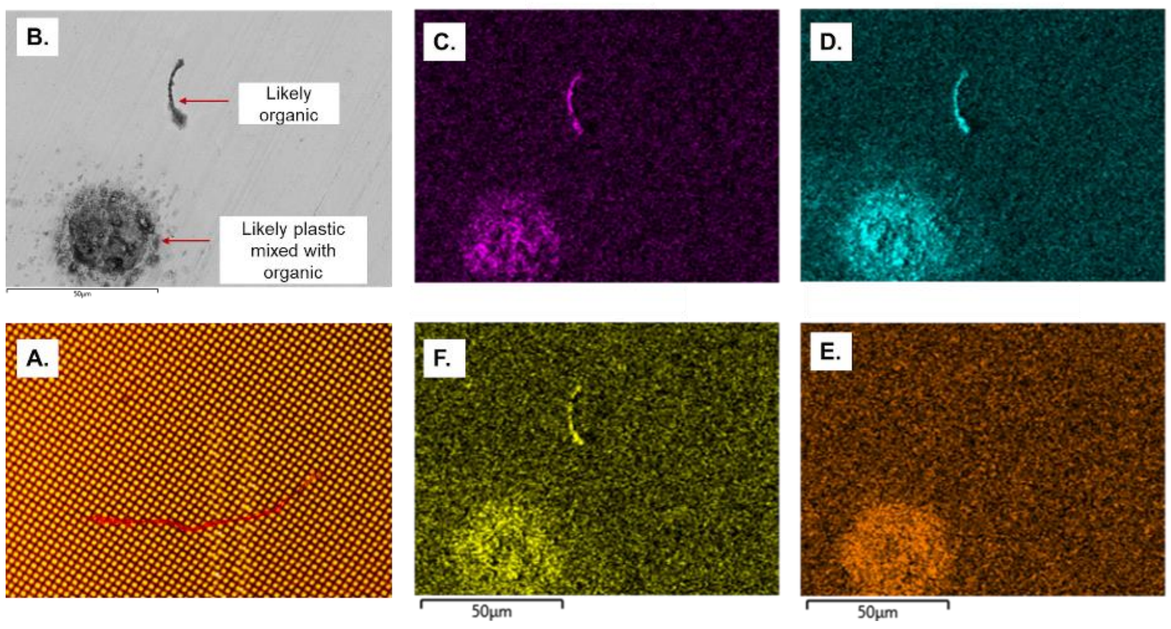

Figure 1. Examples of A. optical image, and B. SEM image of particles in precipitation samples, and the elemental analysis of image B showing presence of C. carbon, D. oxygen, E. chlorine, and F. nitrogen. While C, O and N suggest organic material, C,O, and Cl could potentially be a plastic such as Polyvinylchloride.

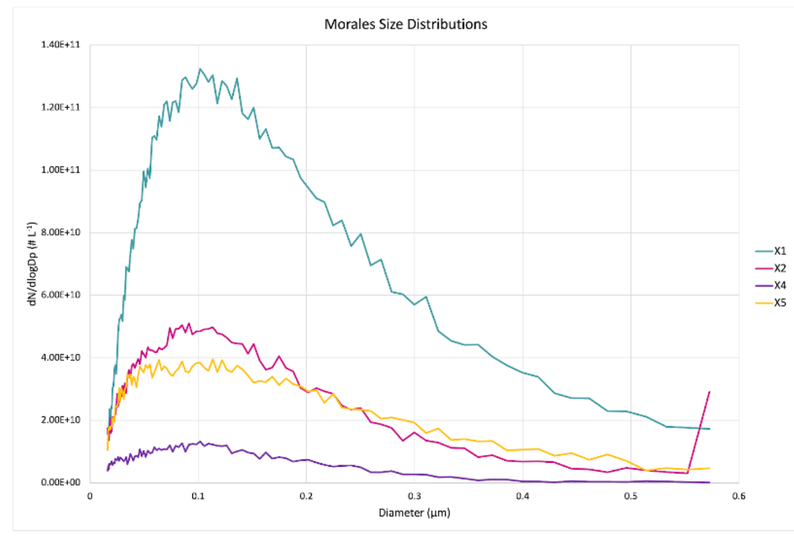

Figure 2. Number size distributions of plastic precursor colloids collected from sewer pipe repair sites that were nebulized and measured using a scanning mobility particle sizer (SMPS)

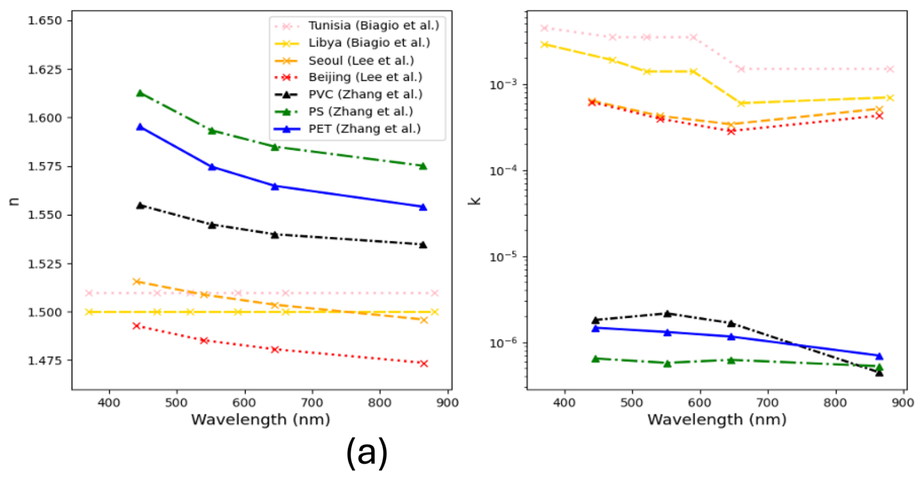

Figure 3. AMP and dust real (n) and imaginary (k) parts of the refractive index collected from literature. Values for Polyvinylchloride (PVC), Polystyrene (PS), and Polyester (PET, specifically, polyethylene terephthalate) at the MAIA relevant wavelengths 440 nm, 550 nm, 640 nm, and 860 nm came from [6]. PET and PS values were collected using a combined spectroscopic ellipsometry (SE) and ray-tracing method, PVC values were collected using a double optical pathlength transmission method. Saharan dust (Tunisia and Libya) values were calculated using Mie approximations [7]. Asian dust (Beijing and Seoul) values were calculated from previously analyzed mineral compositions using Maxwell-Garnett and Bruggemen approximations [8]. Microplastics show significantly different k values by 2-3 orders of magnitude from the Saharan and Asian dusts.

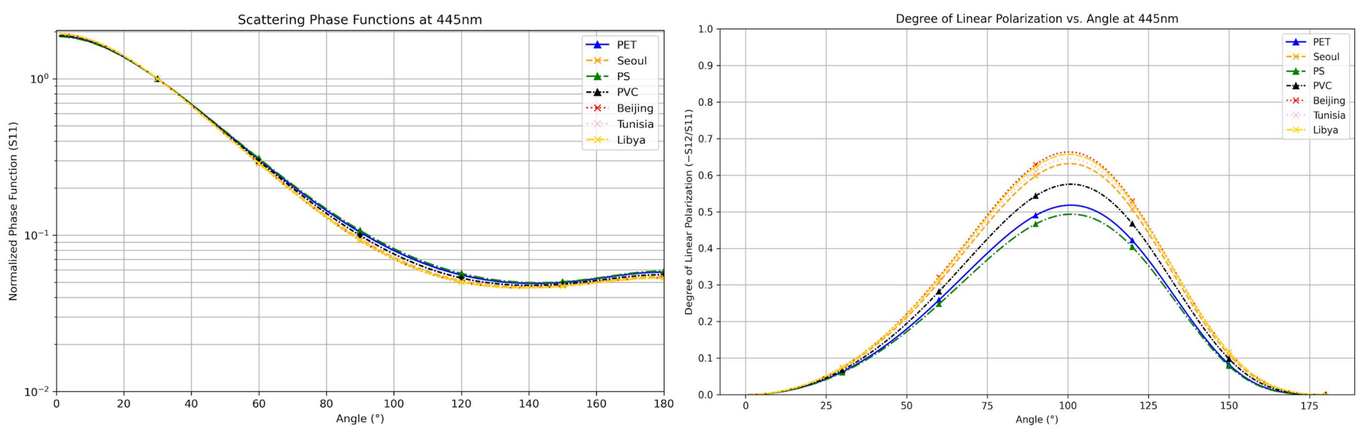

Figure 4. (a) Scattering phase functions of AMPs and dusts from the GRASP spheroid model at a wavelength of 445 nm. This wavelength was chosen as it shows the greatest difference in scattering at forward, mid, and backscatter angles between the particulates. AMPs scatter more than the dusts at mid and backscatter angles, while dusts scatter more in the forward angles. b) Degree of linear polarization (DoLR) for AMPs and dusts at 445 nm from the GRASP spheroid model. 445 nm showed the greatest separation in DoLP values at mid-angles (70 to 125°) between the particulate types. Dusts consistently display a higher DoLR than AMPs. Dusts exhibit a relatively tight grouping with maximum DoLR of ~0.65 while PET and PS group together around 0.5 and PVC lies between the two groups.

The preliminary results indicate that, for the exact same size distribution, it is possible to differentiate between AMPs and dusts as well other spherical aerosol particles for observations made over a range of angles by the JPL's Multi-Angle Imager for Aerosols (MAIA), confirming the potential of the MAIA instrument to retrieve loadings and fractions of atmospheric micro and nano-sized plastics.

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Publications: Tedder, C., A.V. Johnson, G. Prabhakar, and O. Kalashnikova: Distinguishing between atmospheric microplastics and natural aerosols with scattering and polarization. In prep for GRL.

Johnson, A.V. and G. Prabhakar (2024): Understanding Microplastic Aerosols: Clouds, Precipitation, and Beyond. Poster, AAAR Annual Meeting.

Tedder, C., A.V. Johnson, G. Prabhakar, and O. Kalashnikova (2025): Remote Sensing of Microplastic Aerosols using GRASP Open Spheroid Modeling. Talk, AAAR Annual Meeting.

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