MAVEN/IUVS IN THE SKY WITH DUST AND WATER-ICE CLOUD PARTICLES.

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Introduction

Aerosols are an important aspect of the Martian climate but their diurnal variability is largely unknown. Dust is ubiquitous in the lower Martian atmosphere, absorbing and scattering incident solar radiation which warms or cools the troposphere depending on local conditions. Therefore, the thermal state of the atmosphere is quite sensitive to the abundance and distribution of airborne dust (Kahre, Murphy, Newman, Wilson, Cantor, Lemmon and Wolff, 2017). Water-ice clouds also play a role in the climate, though often to a lesser extent than dust. These clouds absorb in the infrared and consequently they influence the global temperature structure and water vapor transport (Clancy, Montmessin, Benson, Daerden, Colaprete and Wolff, 2017). Unfortunately, many sun-synchronous spacecraft did not take observations that allowed for local time monitoring of these aerosols, and thus their diurnally variable properties (spatial extent, optical depth, etc.) are unknown. Global circulation models (GCMs) can predict properties of these aerosols, but they would benefit from derivations of these properties from observations (Barnes, Haberle, Wilson, Lewis, Murphey and Read, 2017).

The Imaging Ultraviolet Spectrograph (IUVS) instrument aboard the Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft takes recurrent spectral images of the Martian atmosphere and surface. It takes data between 205 and 306 nm in its mid-ultraviolet channel and has a spatial resolution of about 7 km by 7 km at apoapsis (McClintock, Schneider, Holsclaw, Clarke, Hoskins, Stewart, Montmessin, Yelle and Deighan, 2015). MAVEN has an elliptical orbit with a period of approximately 4.5 hours, and consequently IUVS is uniquely suited to monitoring the diurnal evolution of both dust and water ice in the ultraviolet. In practice, the elliptical orbit allows it to image a location at several local times spread across six hours of local time.

In this work, we will perform retrievals on a subset of IUVS data from Mars year (MY) 33 that shows significant diurnal variability of water-ice clouds and compare our retrieved values to GCM simulations. We will investigate this data using radiative transfer techniques, which will provide both dust and water-ice optical depths over swaths of the planet. We ultimately hope to compare these results to models in order to better constrain them and examine whether the water inventory of these models is consistent with our retrievals. To do this, we obtained simulations from the LMD GCM (Forget, Hourdin, Fournier, Hourdin, Talagrand, Collins, Lewis, Read and Huot, 1999) and NASA Ames GCM (Haberle, Kahre, Hollingsworth, Montmessin, Wilson, Urata, Brecht, Wolff, Kling and Schaeffer, 2019; Kahre, Wilson, Brecht, Haberle, Harman and Urata, 2022). Having a better handle on Mars' water inventory will help improve models, which may be particularly significant when looking at the planet's atmospheric evolution.

Radiative transfer

To study these aerosols in detail, one typically uses radiative transfer techniques. Performing these retrievals is challenging as one needs to simultaneously specify the single scattering albedo and single-scattering phase function of each aerosol included in the model in a self-consistent manner, and also specify the surface phase function, Rayleigh scattering optical depth, etc. Fortunately, we recently determined the single-scattering albedo of dust in IUVS' spectral range (and the associated phase function) and can thus set the dust's radiative properties (Connour et al 2021, under review). We use the simulations to set the Rayleigh scattering optical depth. We are currently using spherically shaped water-ice particles, but are investigating simulations of radiative properties using a more realistic particle shape (Wolff, Clancy, Kahre, Haberle, Forget, Cantor and Malin, 2019). With these values in hand, we can use radiative transfer techniques on IUVS data to uniquely determine optical depths of dust and water-ice aerosols (see figure 1).

We used the DISORT as the core radiative transfer algorithm (Stamnes, Tsay, Wiscombe and Jayaweera, 1988). We used publicly available pyRT_DISORT as the pre-processing front end to make the required inputs (Connour and Wolff, 2021).

We show preliminary results of our retrievals in figure 2. Our retrievals yield sensible values of dust optical depths for this season. Our retrievals of water-ice optical depths show clouds that roughly match the clouds

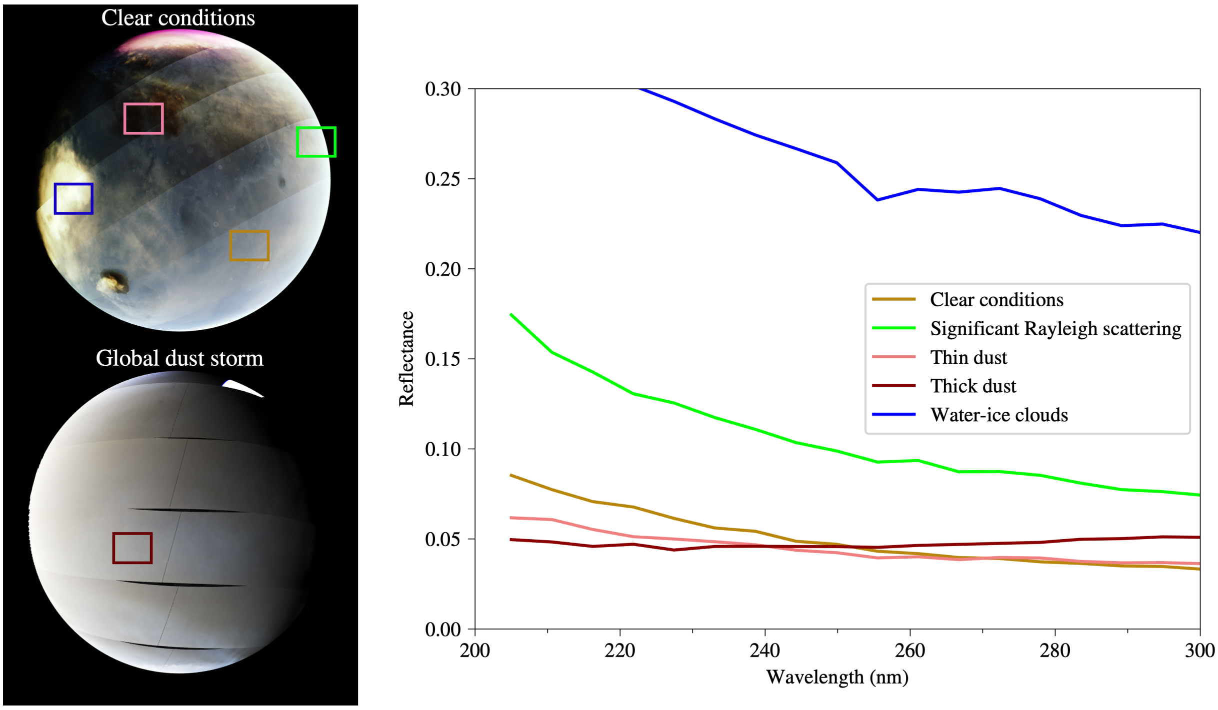

Figure 1: Spectral variability seen in IUVS data over a range of physical conditions. In both images north is oriented upwards. The top image (orbit 3459) shows clear conditions, localized dust storms, and thick water-ice clouds whereas the bottom image (orbit 7414) shows thick dust present during the MY 34 GDS. Both images are enhanced-color projections representing what IUVS observed at apoapsis. During clear conditions IUVS sees relatively featureless spectra, with an increase in brightnesses at shorter wavelengths due to some Rayleigh scattering. Relatively small amounts of dust show similar reflectance values at longer wavelengths but show lower reflectance values at shorter wavelengths as this dust obscures some of the Rayleigh scattering. Optically thick dust continues this trend at shorter wavelengths but produces enough backscatter to increase reflectances at longer wavelengths. Water-ice clouds backscatter much more efficiently than dust and thus are significantly brighter. We can leverage these reflectance values along with the spectral shapes to determine the physical characteristics of aerosols present in IUVS data.

seen in the false-color image of this location. The optical depths show higher values than values seen at this season and local time in previous Mars years. We are investigating the cause of this issue and once resolved will continue with retrievals on many subsequent orbits.

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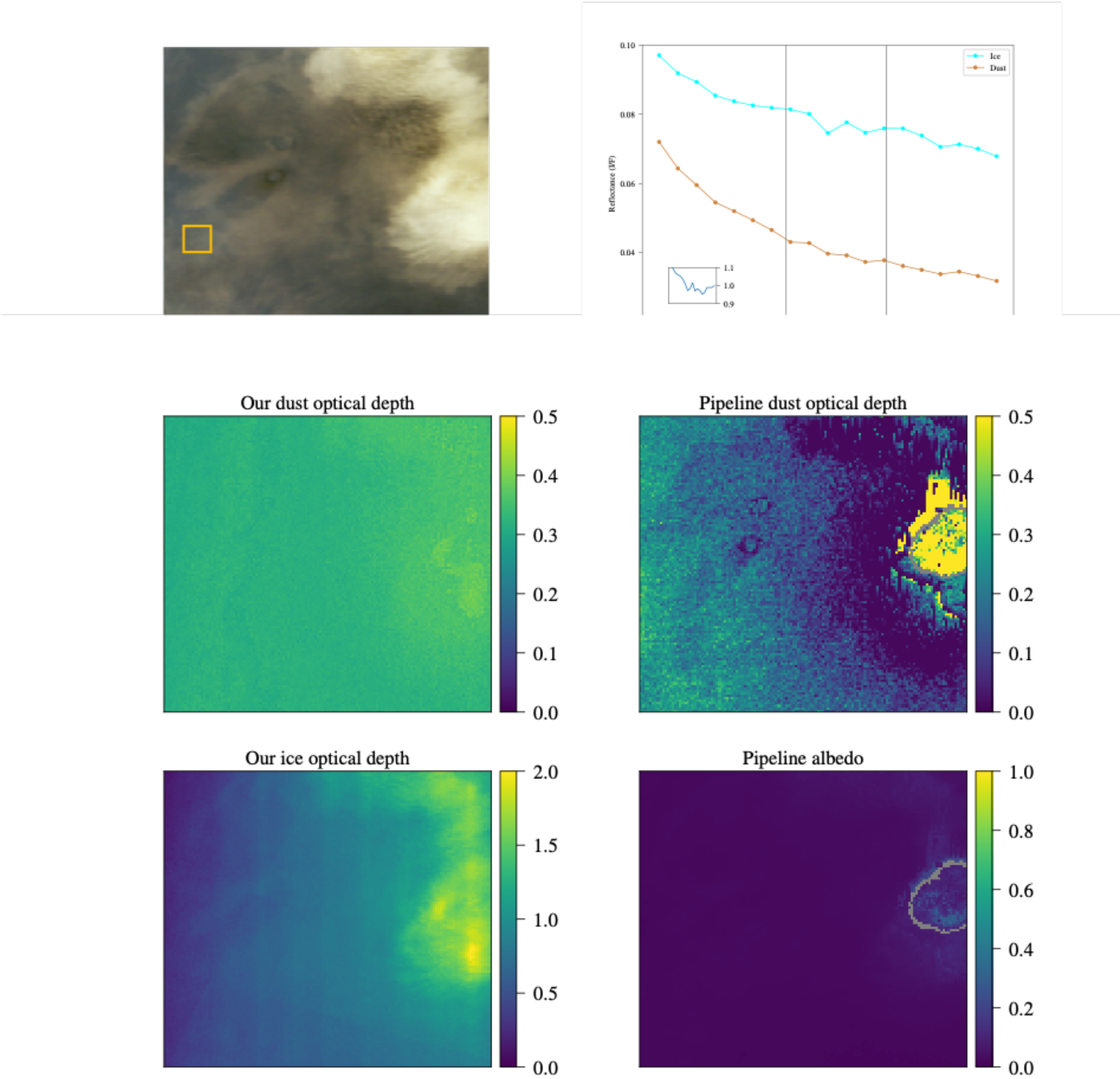

Figure 2: Preliminary results of our updated retrievals. The top left panel shows a false-color image from a subset of an IUVS image (orbit 3453; MY 33, L_s = 182.0°. The top right panel shows spectra of dust and ice in the image. The remaining left hand panels show our retrievals of dust and water-ice optical depths. The dust values are consistent with seasonally averaged values. The water-ice optical depths are higher than expected but show qualitative similarities with clouds seen in false-color image. The right hand panels show retrieved values from the pipeline, which retrieves surface albedo, dust optical depth, and ozone. The addition of clouds to the retrieval (unsurprisingly) has significant effects on the retrieved dust and albedo values.