The MEX/OMEGA Limb Dataset: Description, Analysis Tools, Initial Results. M. J. Wolff[1] , M. Vincendon[2], B. Gondet[2], J-P Bibring[2], and D. Flittner[3], [1]Space Science Institute (4750 Walnut St, Ste 205, Boulder, CO 80301, mjwolff@spacescience.org), [2]Institut d'Astrophysique Spatiale, U. Paris-Sud, [3]NASA-Langley Research Center.

Introduction: Since the beginning of the mission in 2004, the Mars Express (MEx) spacecraft has routinely obtained limb observations using its complement of instruments [1]. Among the MEx instruments, we are interested specifically in the Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (OMEGA) imaging spectrometer [2]. With its 1 mrad IFOV and 3 spectral bands, OMEGA is able to sample the atmosphere with a spatial resolution on the kilometer-scale (depending on position in orbit) and a spectral range of 0.5-5.1 μm (sampled by more than 300 channels) [3,4]. As a result, the OMEGA data set represents a useful opportunity to characterize vertical profiles of aerosol properties, including abundance, composition, and particle size.

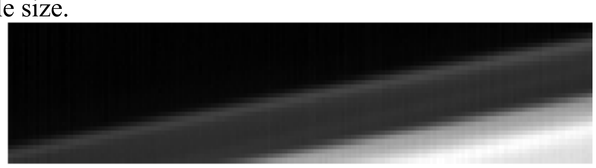
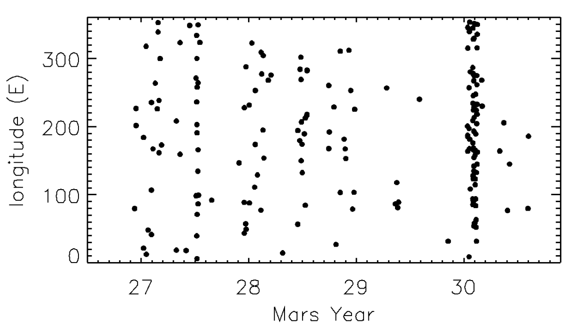


Figure 2 Limb image at 0.5 mm near 12 E, -44 N at L_S=18. ~45 km layer is water ice cloud [8]

The OMEGA Limb Dataset: Because limb data collection is done entirely by slewing the spacecraft (*i.e.*, no use of gimbals or pointing mirrors), such "routine" observations are not synonymous with frequent, synoptic, or systematic. From 2004 through early 2011, when one of the detectors failed, OMEGA collected about 650 limb observations. However, the complexity of the spacecraft planning and maneuvers prevents some observations from having adequate vertical resolution sufficient illumination, and full spectral range. A manual inspection of the data cubes demonstrates that there are 97 sets of high quality profiles and 83 sets of moderate qaulity data (spatial resolution near a scale-height, high incidence angles), i.e. "usable limbs". 46 additional lower quality observations are also available.



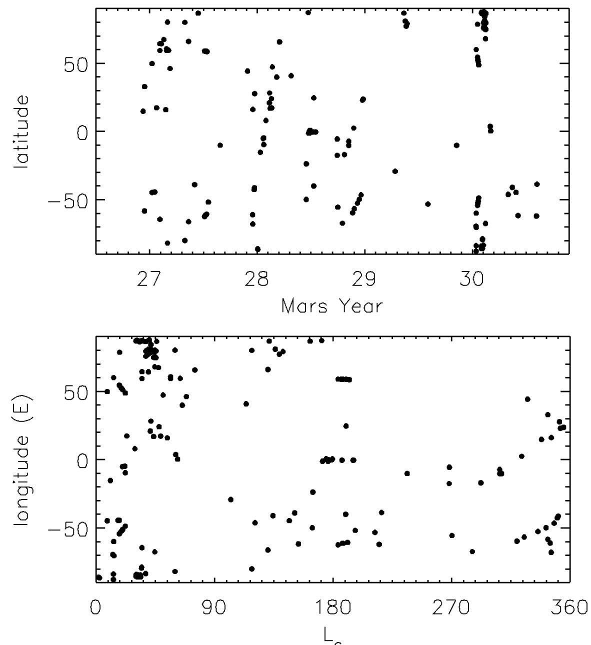


Figure 1 spatial and temporal distribution of usable OMEGA limb observations.

Extracting Limb Profiles: The OMEGA data rarely offer profiles that are parallel to either lines or columns in the images. However, assuming that a profile (by definition) is perpendicular to constant altitude/pressure surfaces, we are able to extract individual profiles with a simple process:

1. Use altitude image to fit analytical function to surfaces of constant altitude.
2. Derivative of function gives slope of parallel line → calculate slope of orthogonal line
3. Use slope map, calculate a profile path (in x,y) for each <<starting point>> of the limb (this can be along both rows and columns; above example is simpler case)
4. Each profile has the original image geometry coordinates as a function of altitude → allows for extraction of spectra and other metadata.

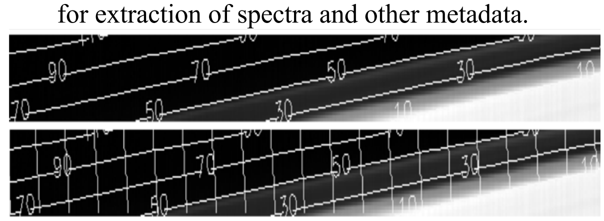


Figure 3 Limb observation in Fig 1 with constant alt surfaces labeled and every 20th extracted profile.

Menagerie of Geometries: In Figs 1 and 3, the short-axis is the cross track direction, so the constant surfaces are largely parallel to the in-track direction. This is often not the case; allowing for only semi-automatic profile extraction.

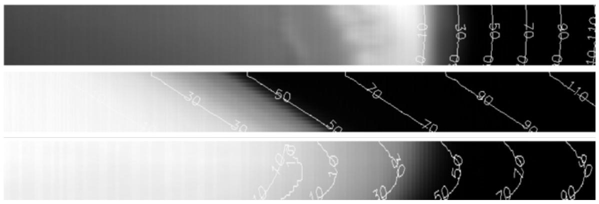


Figure 4. A sample of the along-track variety of geometry found in the "good" or "usable" limb observations..

Retrieval Approach: The radiative transfer is performed using a version of the Gauss-Seidel Limb Scattering (GSLS) code used for terrestrial retrievals by [5]. It agrees well with Monte Carlo models at the 1-2% level for terrestrial applications; similar agreement for tests with Martian conditions including high dust loading. *The code has been modified to allow for the use of tabular phase functions that can also vary with altitude*.

The optimization or “fitting” routine is based upon the public domain MPFIT algorithm [6]. It allows for constraints to be placed upon the retrieved parameters in terms of allowable ranges, etc. and estimation of parameter uncertainty using covariance matrix.

Our approach is to **derive extinction profiles and particle size simultaneously (all components, wavelengths),** i.e., a single iterative procedure. While this is mathematically elegant, it is computationally expensive. While we are working on parallelizing the retrieval with an eye to other datasets, we currently analyzing multiple profiles simultaneously simply using multiple processors.

Example Retrieval: As an example we present in (Figure 5 and Table 1) a retrieval to a profile from a dust-only (i.e., no water ice) limb at L_S=85, 52 N, 273 E. The 5 wavelengths used (red to blue): 1.29, 1.52, 1.79, 2.23, 2.46 µm.

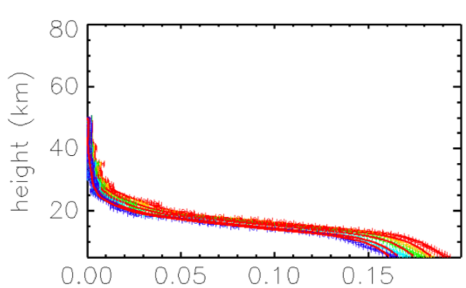


Figure 5 – model data comparison (symbols – data, Lines – model) for the dust-only limb.

Altitude	R_{eff}	σ
10	1.24	0.05
15	1.00	0.04
25	0.45	0.09
35	0.14	0.92
45	0.47	2.9

Table 1. Particle sizes retrieved for the model fits showsn in Figure 5.

The limits in both extinction profiles (K) and particles size tend to be well represented by the size of the retrieval parameter uncertainties. In the example, K < 0.0001 / km above 30 km; illustrating an effective limit for r_{eff} retrievals.

Analysis Plans: As can be seen in Figure 2, the distributions of the limb observations do not lend themselves to studies of specific locations or full seasonal trends. Nevertheless, we are pursuing several thematic investigations and will present the results in our poster:

1. Improvements in the dust optical properties in the 3-5 µm range; the limitations of current values has been discussed by [7]. This will use OMEGA limb and nadir observations during the 2007 dust storm event.
2. An extension of the mesospheric census of aerosols by [7]. The OMEGA data can discriminate among aerosols types and sizes, including CO_2 ice [7,8]
3. characterization of dust and water ice in the lower atmosphere (<40 km) in northern spring.
4. Study of dust and ice aerosols during the 2007 global dust storm"

References: [1] Gondet, B. et al., 2015, 46th LPSC, 1844. [2] Bibring, J-P. et al. 2004, Mars Express: The Scientific Payload, 1240: 37-49. [3] Gondet, B. et al. 2011, 4th MAMO Conference. [4] i.e, Gondet, B. et al. 2017, 6th MAMO Conference. [5] Loughman, R. et al. 2015, Atmospheric Chemistry & Physics 15: 3007-3020. [6] Markwardt, C. 2008, ASP Conference Series, Vol. 411, p. 251-254. [7] Clancy, R. T. et al., 2019, Icarus, 328, 246-273. [8] Vincendon, M. et al. 2011, 4th MAMO Conference.

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