LIMB OBSERVATIONS OF THE MARTIAN ATMOSPHERE WITH MARS EXPRESS' HIGH RESOLUTION STEREO CAMERA.

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Introduction:

Good knowledge about the aerosol distribution and compositions is essential for the understanding of thermodynamic processes in the Martian atmosphere, which in turn is important for the understanding of the Martian climate and the altitude of the upper boundary of the atmosphere. The last point is of special interest for spacecraft aerobreaking manoeuvres.

The Martian atmosphere often shows horizontal layers of haze up to altitudes of about 80 km. These have been described and analysed e.g. by Jaquin et al., 1986, using Viking Orbiter images and by Montmessin et al., 2006, who used SPICAM stellar occultation data. Both showed seasonal and latitudinal changes in the vertical structure of the aerosol distribution and composition. Apart from SPICAM, the High Resolution Stereo Camera (HRSC) is also on board ESA's robotic spacecraft Mars Express. HRSC was build and is operated by the German Aerospace Center (Neukum et al. 2004; Jaumann et al. 2007). Mars Express is orbiting Mars in an elliptical orbit, with HRSC scanning the surface of Mars, primarily for geological research. In addition to that, HRSC has been used to sample the planetary limb.

We examine the HRSC planetary limb data and analyse the seasonal and latitudinal variations of the maximum altitude of the haze layer and of the occurrence of high altitude detached hazes. We make some comparisons with earlier work. In contrast to the SPICAM instrument, HRSC observes the atmosphere during daytime, which makes it possible to compare night and daytime observations.

The HRSC Limb Data:

HRSC is a push broom scanner with nine line sensors pointing in different directions to facilitate stereoscopic imaging. Four of the sensors have colour filters at 440 nm, 530 nm, 750 nm and 970 nm, respectively. The five other sensors all have filters centred at 650 nm. These panchromatic filters have a much wider bandpass than the four colour filters.
The surface observations which are HRSC's main purpose, are usually take while the spacecraft is nadir-tracking near pericentre. Limb observations, however, are mostly made with a pointing of the spacecraft being inertially fixxed in celestial space. This leaves only a small time window to make observations of the limb during descent or ascent. Therefore, usually only a few of the nine sensors can be used for the limb observation. Due to the motion of the spacecraft, the individual image lines are taken at different geographical locations and altitudes. The position of each image pixel above the limb has to be calculated from the spacecraft positioning information (Scholten, pers. comm.). The typical difference in altitude between two neighbouring pixels is between a couple of dozen metres and 150 m. HRSC has been observing the limb occasionally throughout the mission since 2004. So far the northern hemisphere and especially the north polar region, were particularly well covered (Figure 1 and 2).

In Figure 2, we give an overview of the available data, sorted by season (L_S) and latitude. The channel in which the observations have been made is

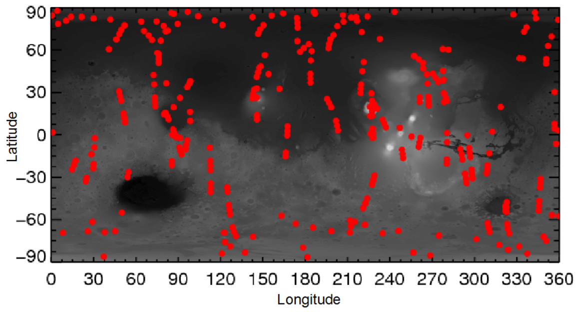


Figure 1: Locations of limb observation over Mars. The dots mark the geographical position of the spot in the line of sight that is closest to the limb during the middle of the observation. Note that a whole observation covers usually a larger region than the circles indicate.

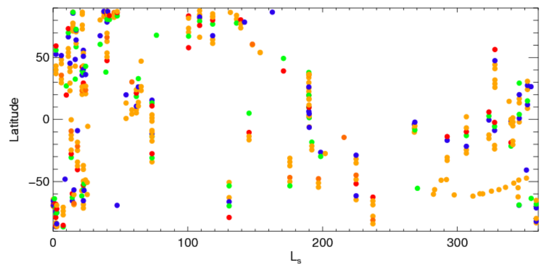


Figure 2: Mars Express HRSC limb observations. The colour of the dots is chosen according to the colour of the used filter.

colour-coded. Most observations were made with the panchromatic channels. There are also many observations with the blue and green sensors and only a few were made in the red and infra red channels. We find the best data coverage in northern spring in the northern most latitudes. For obvious reasons, we do not have any data during polar nights. For most of our actual analysis we sample the five central pixels of the sensor lines. This allows for minimal horizontal averaging.

Analysis:

As an example, Fig. 3 shows images and profiles for the blue, nadir, and green channels from orbit 6104. Al three images show a continuously bright limb haze until an altitude of about 20 km. At higher altitudes the limb haze becomes darker and stratified consistent with the limb profiles described by Jacquin et al., 1986. As Mars Express progresses along its orbit, the limb observations are made at different locations above the surface. The locations of the three profiles in Fig. 3 are still in close proximity of each other, in fact they overlap, but none the less they show different vertical aerosol distributions. Beginning above the North Polar cap and going southward, we observe less reflectivity above 20 km and more reflectivity below 20 km, hinting at different compositions or amounts of aerosols.

It is not possible to obtain and compare profiles at the same location and at the same time with different sensors, but still, averages of profiles over place and season can provide us with information about typical atmospheric conditions. In Fig. 4 we show spectra from the average profiles at three different latitudinal bands between 70°N–90°N, 30°S–30°N, and 90°S–70°S, on the left, centre, and right, respectively. The different symbols and colours represent the different altitudes at which the spectra were sampled. The size of the symbol increases with the number of averaged profiles. There are very few observations above the South Polar region (compare Fig. 1). In the North (and South) Polar region there is almost no signal above 30 km altitude, while around the equator the limb haze remains bright until altitudes of about 60 km. At the poles, the spectrum at 10 km is reddish. At higher altitudes the spectrum gets whiter, indicating smaller particles or higher ice content. At the low latitudes the spectra are reddish up to 40 km. At 60 km we see a more or less white spectrum. Figure 5 shows the maximum altitude of the aerosols as seen by HRSC, depending on season. During aphelion ($L_S \approx 70°$) the maximum altitude of the aerosols that are visible with HRSC is around 40 km. During perihelion ($L_S \approx 250°$) the maximum altitude is around 70 km.

Discussion:

Figure 1 and 2 show that there are plenty of visual and near infra red HRSC observations of the Martian limb available. These show aerosol distributions that change with season and latitude (Fig. 3 and 4). The plots in Fig. 4 show the spectra of the average limb profiles at several altitudes for three latitudinal bands. Two important distinctions can be made between the equatorial and the polar regions. First, the altitude at which aerosol occur is higher in the equatorial region and second, the composition of the aerosols at different altitudes is different. While the spectrum is white around 20 km altitude above the north pole, it is red at the low latitudes.

The seasonal variations of maximum altitude of the aerosols is in good agreement with Jaquin et al. (1986) and with Montmessin et al. (2006). The similarity between Montmessin's results and ours is likely to be due to the large annual variation of atmospheric dust load compared to the diurnal cycle. A much closer look at the data, is forseen to analyse the daily variation of aerosols in the Martian atmosphere. The CO_2- and water-ice aerosols are more likely to change their vertical distribution (above the planetary boundary layer) between day and night than the mineral (dust) aerosols. Spectral information would help to discriminate between these components. HRSC can not provide it, because the observation for the different filters take place at different locations and times (see Fig. 3). An alternative is to fit aerosol models to the inverted profiles. Currently, we are preparing this work.

Mars Express' HRSC limb data present a valuable opportunity to analyse Mars daytime atmospheric dust at a high vertical resolution. This work gives a short overview of the available data and analyses some seasonal and latitudinal properties.

Acknowledgements:

We thank the HRSC Experiment Teams at DLR Berlin and Freie Universität Berlin as well as the Mars a Express Project Teams at ESTEC and ESOC for their successful planning and acquisition of data as well as for making the processed data available to the HRSC Team. We acknowledge the effort of the HRSC Co-Investigator Team members and their associates who have contributed to this investigation in the preparatory phase and in scientific discussions within the Team. For this study, the HRSC Experiment Team of the German Aerospace Center (DLR) in Berlin has provided map-projected HRSC image data, and HRSC Preliminary 200 m DTM(s).

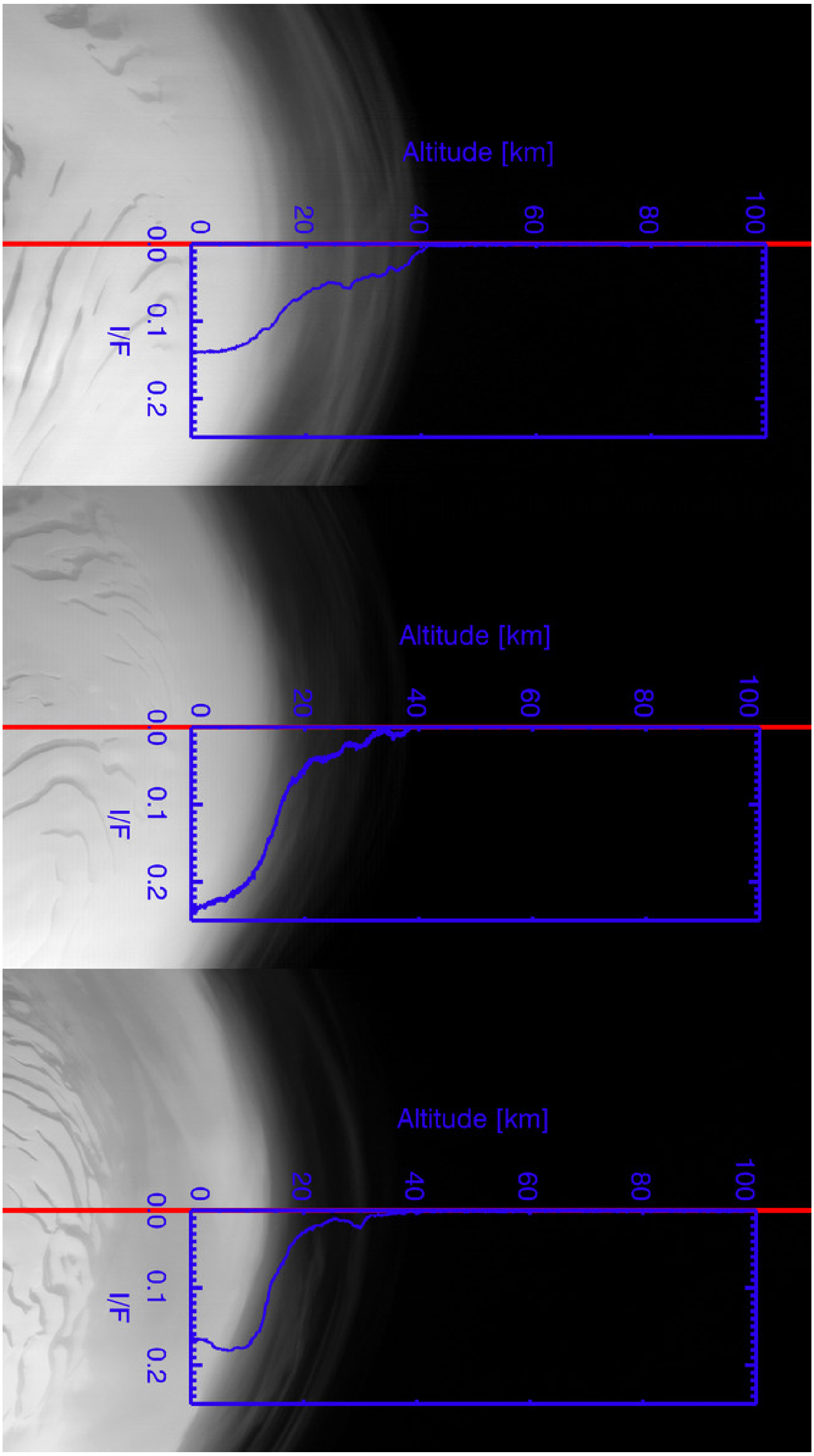
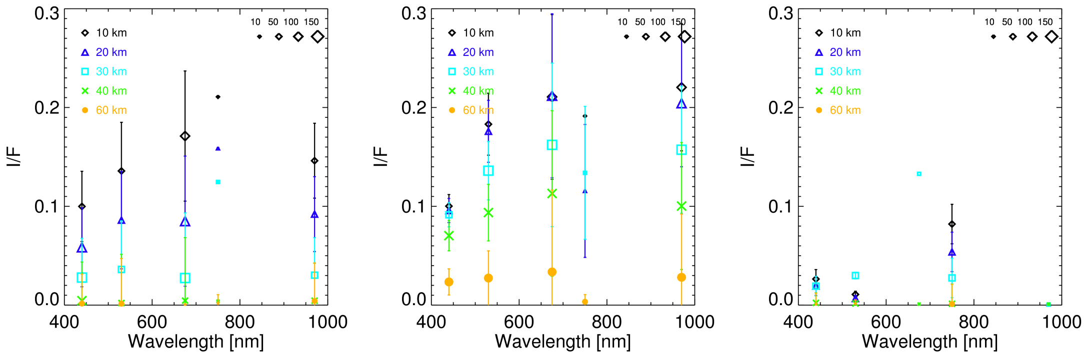


Figure 3: Comparison of blue channel, nadir, and green channel limb observation during orbit 6104. Overlaid I/F Profile between 0 and 100 km above the limb, on the top, the centre, and the bottom, respectively.



(a) 70°N – 90°N (b) 30°S – 30°N (c) 70°S – 90°S

Figure 4: Spectra of the average limb profiles at different altitudes at all seasons. The size of the symbols increases with the sample size.

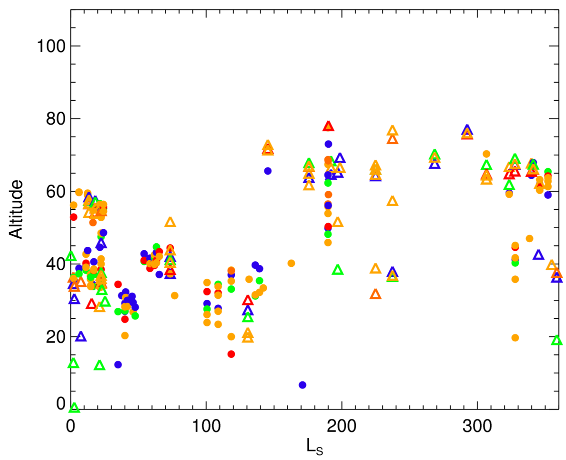


Figure 5: Maximum altitude of aerosols from HRSC limb observations from all latitudes and seasons. The colours represent the different filters of HRSC.

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