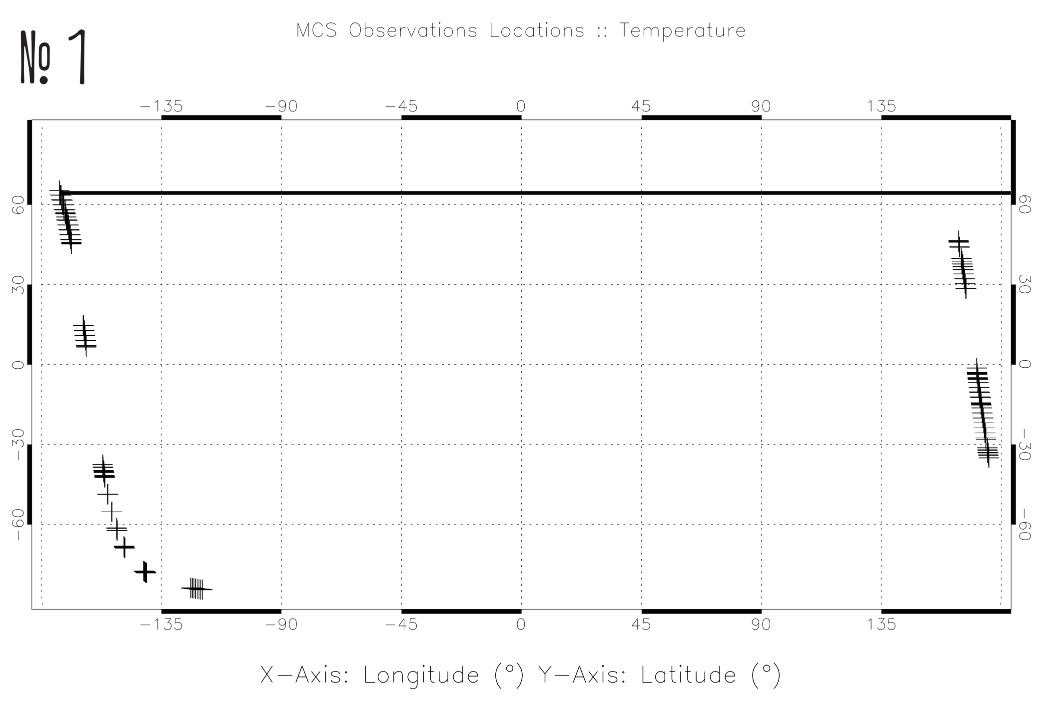

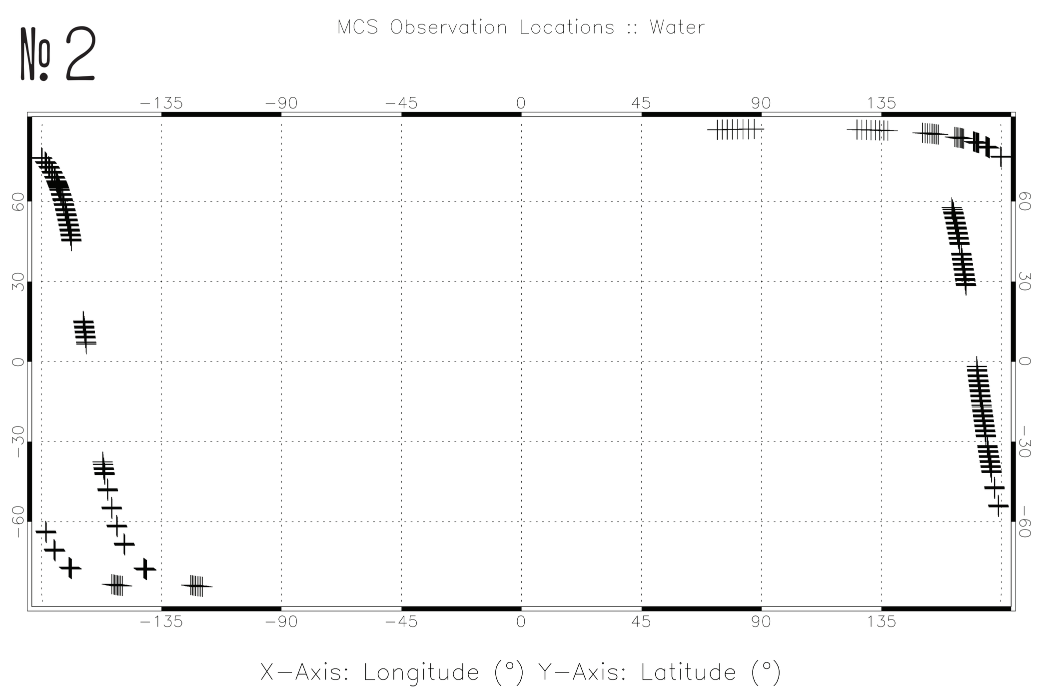

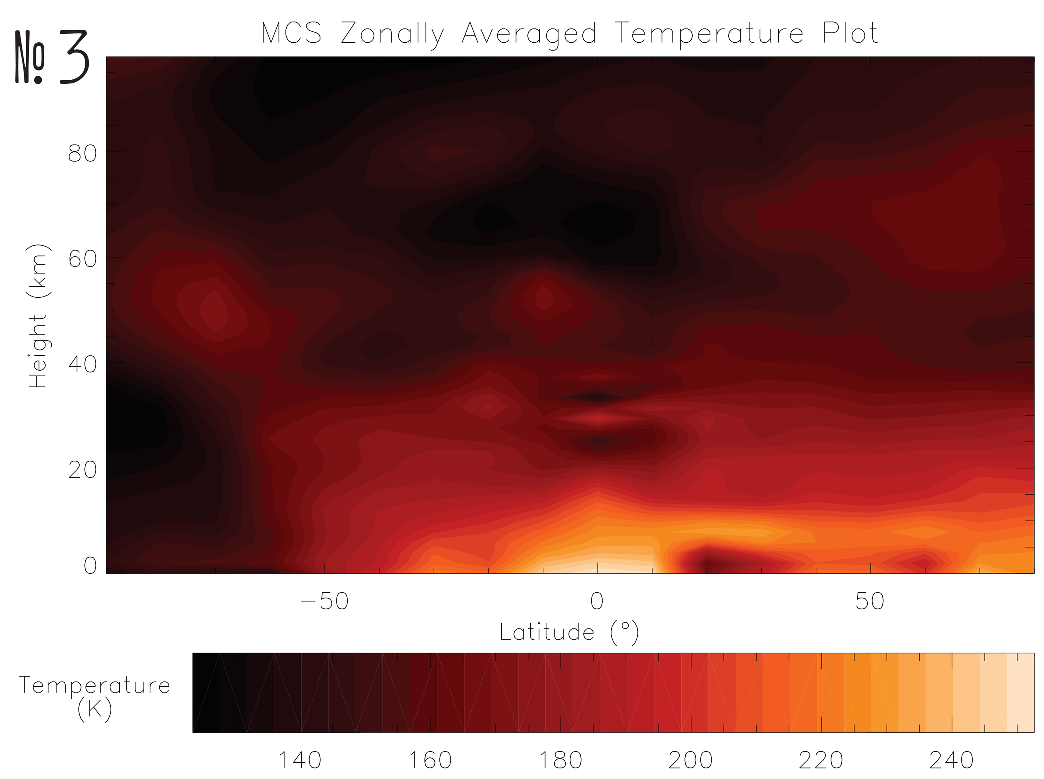

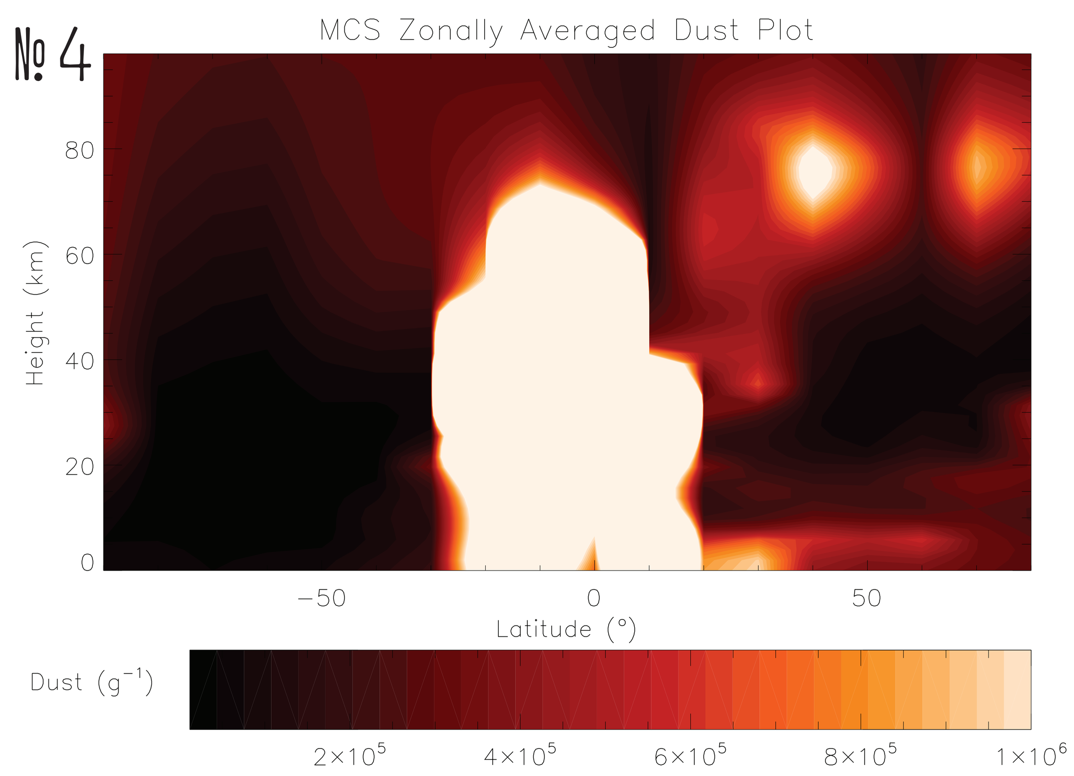

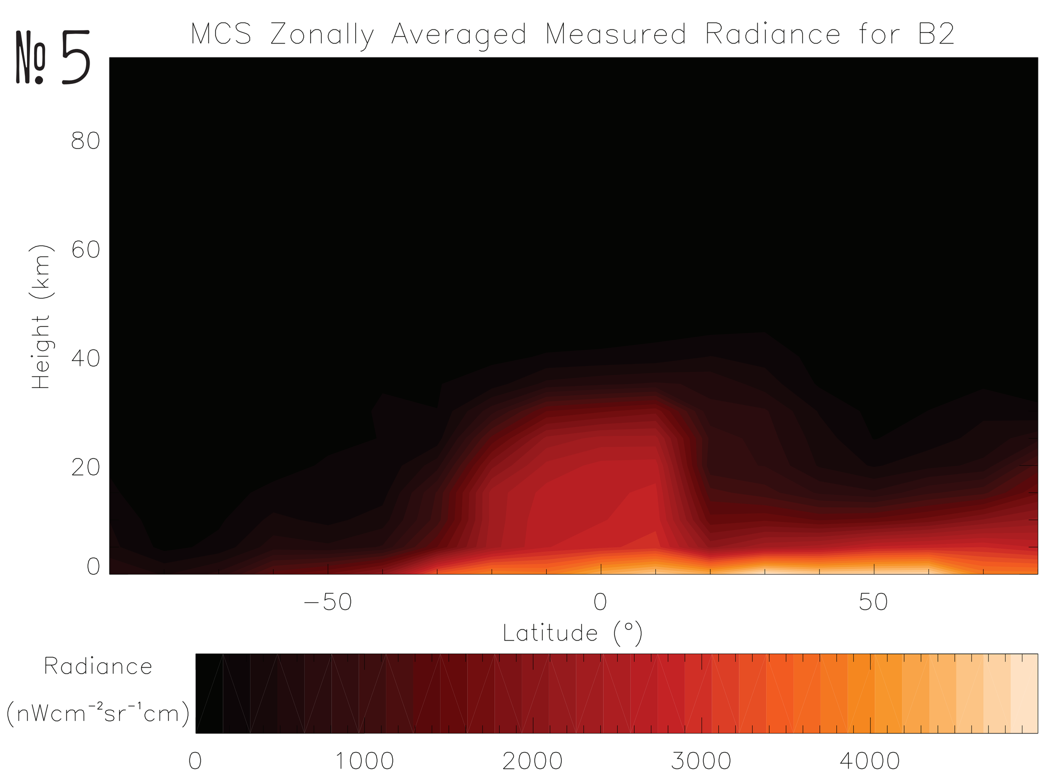

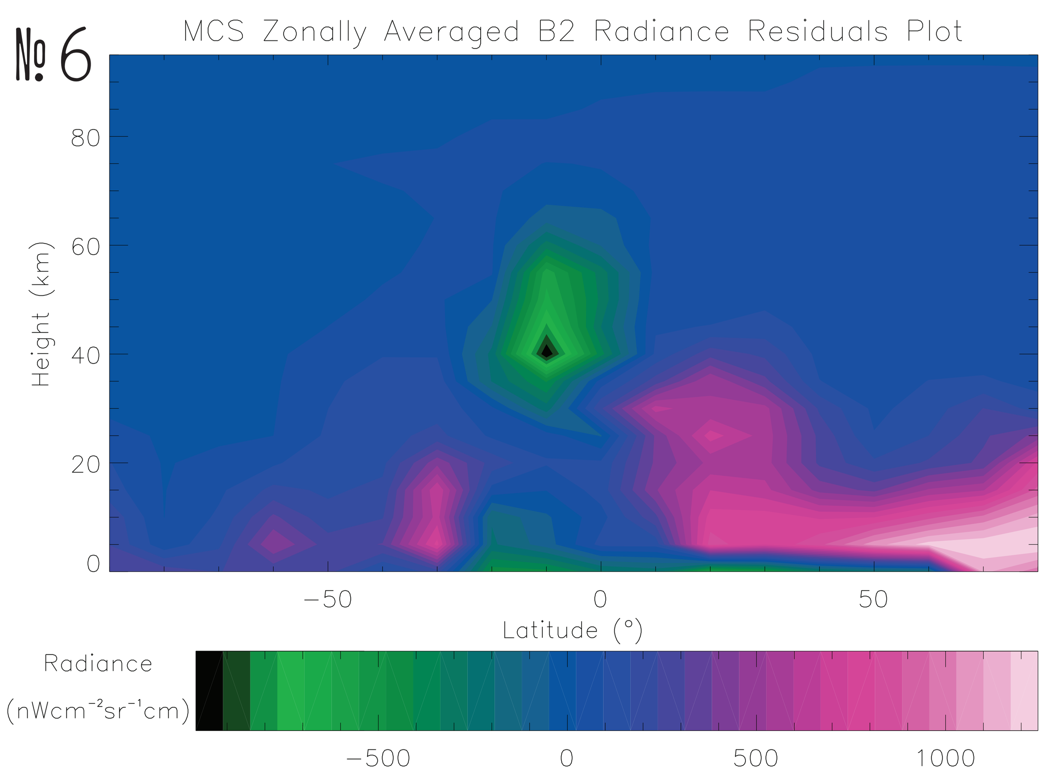

Figure 1 (TL), Figure 2 (BL): Maps showing the locations of the MCS observations used for the first and second stages of the retrievals respectively.
Figure 3 (TM): Zonally averaged (10° latitude bins) temperature plot. **Figure 4 (BM):** Zonally averaged dust plot. The colour scale has been truncated at 1×10^6 g^{-1}.
Figure 5 (TR): Zonally averaged measured radiances in B2. The radiance observed should be due to water and dust with possible contributions from water ice.
Figure 6 (BR): Zonally averaged radiance residuals (*[observed radiances with water vapour] – [synthetic radiance with no water vapour]*) for B2 at L_s = 111.27° .

Preliminary Martian Atmospheric Water Vapour Radiance Analysis with **MCS**

Ramin Lolachi *et al.* (see left)

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Mars Climate Sounder (MCS) is an infra-red radiometer on board NASA's Mars Reconnaissance Orbiter (MRO) launched in August 2005 and now orbiting Mars in a near circular polar orbit. MCS has nine spectral channels in the range 0.3–50 µm. A primary goal of MCS is the global characterization of atmospheric water vapour. We present results of a vertically resolved, zonally averaged analysis during L_s = 111.27° (24th September 2006).

Using the B2 channel (220 cm^{-1}) work was done using the NEMESIS[1] retrieval software to calculate radiance residuals due to water vapour. The direct retrieval of water vapour from MCS observations is very difficult. Instead the retrieval needs to be broken down into a two-stage process, whereby all parameters except water vapour are retrieved first, followed by the water vapour retrieval itself. Initial attempts at retrieval proved extremely challenging.

Daytime MCS observations during northern summer (combining fully calibrated nadir and limb data) were used. A plot of observation locations is given in Figs. 1 & 2.

In the first stage of the analysis temperature, dust, pressure and surface temperature were retrieved (using channels A1–A5) while effectively setting the water vapour abundance to zero (constant VMR to top of atmosphere of 1×10^{-10}). We then follow this up by modelling the radiance (using atmospheric data from the Mars Climate Database[2]) seen in B2 using the previously retrieved parameters. This ought to model the atmosphere as seen by MCS with no water vapour. The 'zero water vapour' radiances in B2 can then be subtracted from the original measurements to generate the radiance residuals. Assuming that the retrievals and modelling are sufficiently accurate the radiance residuals should correspond directly to water vapour abundance as the residuals should be almost entirely due to water vapour alone with other effects having been removed by the subtraction process. For the sake of computational expediency dust was assumed to be non-scattering. All results were then binned in 10° latitude bins and used to produce zonally averaged latitude-altitude maps.

A map of zonally averaged temperature is given in Fig. 3. Results seem broadly physical with the northern hemisphere (experiencing summer) being warmer than the southern hemisphere (experiencing winter) and the temperature maximum occurring in the equatorial region. A relatively large local minimum is observed in the tropics at 20–30° N along with another minimum at ≈70° N. These may be due to local effects caused by the lack of longitudinal coverage in the observations or possibly due to the retrieval method assumptions.

A map of zonally averaged dust with height is given in Fig. 3 measured in specific density (g^{-1}: particles per gram of atmosphere) where the scalebar has been truncated for values >1 × 10^6 g^{-1} to make the dust structure visible. The general trend of more dust in the northern hemisphere than the southern with a maximum at the equator is physical and corresponds to the higher temperatures in the northern and equatorial regions. Higher temperatures aid dust loading in the atmosphere[3]. The rather unphysical result is the appearance of apparent dust layers high in the atmosphere at altitudes between 30 and 80km, with the higher layers and bigger maxima occurring in the northern hemisphere.

A number of explanations are possible. Firstly the high layers seen over the equator may actually be water ice clouds from the aphelion cloud belt which were not accounted for in the retrieval. The expected location of the belt is similar to the observed dust layer. This would not explain the dust layers in other regions, especially the northern hemisphere, which should be too warm for any ice clouds to be present. Another possibility is the extended FOV wings effect of MCS. In the majority of cases the observed high dust layer has a matching layer on the surface. The high layer may then be a retrieval artefact caused by the FOV wings of higher altitude detectors (for limb observations). The extended wings of these higher detectors allow them to 'see' the lower dust layer and then cause it to alias higher up. Yet another possibility is the choice of not using B1 (a dust and water ice channel) in the retrievals, since then less information is used to constrain the dust. The reason that B1 was not used in the retrieval is that it is currently proving very challenging to get satisfactory fits to the data due its sensitivity to water ice (not considered in this study) and the FOV effects. A final option is that the retrieval assumptions used (i.e. non-scattering, well mixed vertical profile to the top of the atmosphere) are responsible. It is likely that a combination of these effects is responsible for the observed results.

A map of the observed radiances for B2 is given in Fig. 5. The expected trend of more radiance in the northern hemisphere corresponding to higher water vapour abundance is seen. However this alone is not enough to prove that the radiance seen in B2 is mainly due to water vapour, as dust is likely to have a profound contribution to the radiation in this channel. Additionally water ice clouds may also be contributing to the radiance in B2, though this is beyond the scope of the current investigation. This argument is further supported by the observed correlation between the dust opacity in Fig. 4 and the measured radiance in B2. Alternatively, the observed correlation may indicate interaction between dust and water vapour.

The radiance residuals for B2 are presented in Fig. 6. Given the problems described above it is unlikely that the residual radiances observed have been entirely disentangled from effects other than water. It is likely that the decision of not using B1 for the dust retrieval means that dust is not as well constrained in the B2 spectral region. Despite this the effect of dust seems to have been at least partially removed, given the minimum of residuals for regions of expected low water content. Additionally a maximum in the radiance residuals is seen at latitudes near the pole which correlates well with the recent measurements of water vapour[4–7]. Further evidence of water contributing to the observed radiance is seen by the fact that highest values for radiance residuals are confined to the bottom 20–40km of the atmosphere (being smallest at the pole and largest near the equator which approximately match the likely heights of the condensation level). The fact that the maxima of the residuals continue to altitudes that are few kilometres higher than the likely height of the condensation level may be due to the FOV wing effect described above. Finally the observed minima (largest magnitude negative residuals) in residuals near the ground in the equatorial to mid-latitude regions are likely to be due to an extended FOV wing problem. The straight edges at the top of this negative residuals layer at the bottom of the atmosphere are due to the coarse altitude bin widths of 5km. As described previously, because of the wings, the FOVs for the lowest detectors will 'see' the ground through the atmosphere. This provides a warm background for the atmosphere meaning spectral lines are seen in absorption rather than emission, resulting in the negative radiance residuals observed. The reason the effect is not observed at latitudes outside this region is probably due to the colder surface temperatures at the poles and southern hemisphere (in winter) so the ground is not warmer than the atmosphere above it.

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