VALIDATION AND INTER-COMPARISON OF LIMB SOUNDING PROFILES FROM MRO/MCS AND MGS/TES.
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Introduction: We exploit the relative stability and repeatability of the Mars atmosphere at aphelion (from L_s=70° to L_s=80°) for an inter-comparison of Mars Global Surveyor/Thermal Emission Spectrometer (MGS/TES) and Mars Reconnaissance Orbiter/Mars Climate Sounder (MRO/MCS) nighttime temperature profiles and aerosol opacity profiles in Mars years 25, 26, 29, 30, and 31. Together the TES and MCS datasets provide an extended climatology for this planetary atmosphere. However, in order to draw reliable conclusions from studies that use both datasets, it is first necessary to cross-calibrate the data, so that we may understand the similarities, differences, and limitations of the data and the level of agreement between them. As a standard of comparison we employ temperature profiles obtained by radio occultation methods during the MGS mission in Mars years 24, 25, and 26 (Fig. 1) [1]. Here we discuss results employing MY 26 radio science data only. A more complete discussion of our methodology and results may be found in [2].

Data: Zonal mean nighttime temperature profiles were extracted from the radio science [1], TES limb sounding [3], and MCS [4] version 4.1 datasets, for 5 degree latitude bands corresponding to the available radio science data (Fig.1). Fig. 2 illustrates the profiles obtained for the southernmost latitude bin selections.

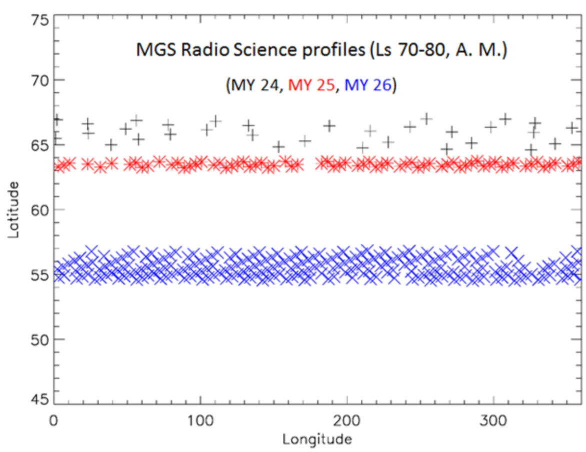

Figure 1. Latitude-longitude plot of the locations of the available MGS/RS profiles for L_s= 70°-80°. The locations are color coded by year, with MY 24 (n=36) in black (+ symbols), MY 25 (n=70) in red (star symbols), and MY 26 (n=226) in blue (cross symbols).

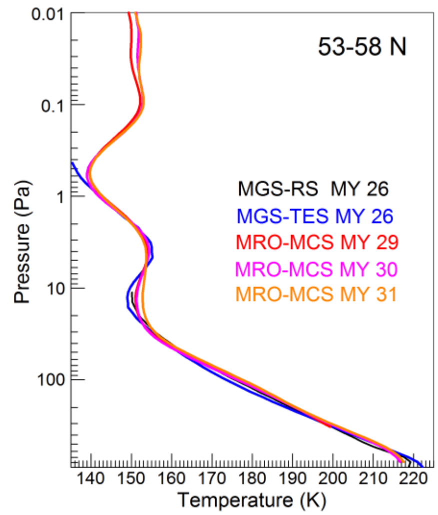

Figure 2. Color coded zonal mean temperature profiles for the 53°-58° N latitude samples of Table 1. The TES and RS samples were obtained in the same Mars year but at different local solar times (~02:35 and ~03:44 respectively). Error bars have been omitted for clarity; standard deviations for all curves are typically << ± 5 K (see [2] for further details).

The repeatability and relative simplicity of the zonal mean vertical temperature structure for these latitudes during the northern spring (aphelion) season are important advantages for intercomparison purposes.

Methods and results: Interpolation in log pressure space was employed to represent all three datasets in a common vertical scale (the MCS standard pressure levels [4]). Temperature differences in the sense TES-RS and MCS-RS were obtained by subtraction for each pressure level. The differences found are plotted in the left hand panel of Fig. 3. Table 1 summarizes the ensemble mean temperature differences found for each comparison. The ensemble mean differences are < 2 K for all of the comparisons of the profiles of Fig. 2; these values lie within the estimated absolute temperature errors for both TES [5] and MCS [4]. While a number of caveats must be noted [2], these results suggest that nighttime temperature values obtained by TES and MCS at the same seasons and locations may be compared directly.

Latitudes (degrees)	Comparison	Mean Δt (K)	σ (K)	Max Δt (K)
53-58 N	TES MY 26 - RS MY 26	1.3	0.6	2.33
	MCS MY 29 - RS MY26	0.9	0.5	1.49
	MCS MY 30 - RS MY 26	1.1	0.6	-2.58
	MCS MY 31 - RS MY 26	1.5	0.8	3.01
61-66 N	TES MY 25 - RS MY 25	1.8	0.7	2.82
	MCS MY 29 - RS MY 25	1.2	1.0	3.23
	MCS MY 30 - RS MY 25	1.4	1.2	3.05
	MCS MY 31 - RS MY 25	2.1	0.9	3.37
63-68 N	TES MY 26 - RS MY 24	1.9	0.7	-3.11
	MCS MY 29 - RS MY 24	1.8	1.4	4.16
	MCS MY 30 - RS MY 24	1.2	1.0	3.42
	MCS MY 31 - RS MY 24	1.8	1.2	4.16

Table 1. Summary of temperature differences found in level by level comparisons of zonal mean TES and MCS temperature profiles in the indicated Mars years.

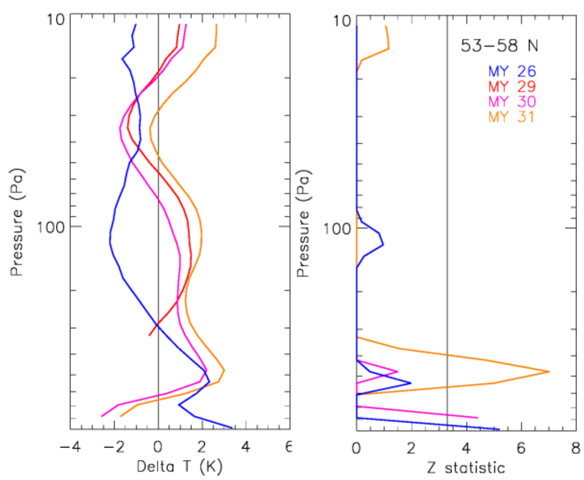

Figure 3. Temperature differences (K) and values of the *z* statistic by pressure level for the 53°-58° N latitude samples. Left: The temperature differences are obtained by subtracting the radio science MY 26 temperatures from the TES and MCS temperatures. Averaged differences over all pressure levels for these profiles are listed in Table 1. Right: Values of the *z* statistic by pressure level. The 99.9% significance level (*z*=3.29) is indicated by a vertical line in the right hand panel.

Statistical evaluation. It is desirable to have a measure of the statistical significance of the differences of temeperatures noted, as this will allow us to focus on differences that may be due to inter-annual variability, systematic biases or observational differences. From a statistical perspective, we view the individual measurements that gave rise to the mean values as samples drawn from a much larger population. We ask: What is the probability that the two samples may have been drawn from the same underlying population? That is, what is the likelihood that both of our derived mean temperatures could arise from different instances of random sampling of the same atmosphere? This is a well-understood problem in statistics. Here we adapt a standard *z* test (see [2]) for comparing the differences of sample means. The right hand panel of Fig. 3 illustrates *z* values by pressure level for the temperature differences noted in the left panel. This test draws our attention to the 500 Pa pressure level in the MCS temperature profile for MY31, as an instance where the temperature differences between this year and the RS temperatures of MY 26 are larger than would be expected to occur by chance, if the samples were drawn from the same atmosphere. We interpret this as an example of minor but real inter-annual variability of the aphelion season Mars atmosphere.

Discusssion: The ~1 hr difference in the local times of the TES and MCS observations has been of concern for investigators seeking to construct a multi-year climatology of the Mars atmosphere [6]. We have been unable to detect any systematic differences of TES and MCS nighttime temperatures linked with the difference in observation times.

Aphelion season nighttime atmospheric temperature profiles from TES and MCS have been validated through comparison with MGS radio science temperature profiles for the same season and latitudes. Ensemble mean temperature differences found with respect to zonal mean radio science profiles lie within the stated absolute temperature error ranges for each instrument.

Our study has additionally considered the similarities and differences in dust and water ice aerosol opacities measured by TES and MCS at the same latitudes and seasons. Space limitations prevent the inclusion of those results here but we anticipate that these will be included in the presentation at the conference.

References: [1] Hinson D. L. et al. (2004), *JGR 109*, E01002. [2] Shirley, J. H. et al. (2014), Temperatures and aerosol opacities of the Mars atmosphere at aphelion, *Icarus*, (in revision). [3] Guzewich, S. D. et al. (2013), *JGR 118*, 1177-1194. [4] Kleinböhl, A., et al. (2009), *JGR 114*, E10006. [5] Conrath, B. J., et al. (2000), *JGR 105* (E4) 9509-9519. [6] Bandfield, J. L. et al. (2013), *Icarus*, doi:10.1016/j.icarus.2013.03.007.
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