The Exomars Climate Sounder (EMCS) Investigation

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1. Introduction

The ExoMars Climate Sounder (EMCS) investigation is developed at the Jet Propulsion Laboratory (Principal Investigator J. T. Schofield) in collaboration with an international scientific team from France, the United Kingdom and the USA.

EMCS plans to map daily, global, pole-to-pole profiles of temperature, dust, water and CO_2 ices, and water vapor from the proposed 2016 ExoMars Trace Gas Orbiter (EMTGO). These profiles are to be assimilated into Mars General Circulation Models (MGCMs) to generate global, interpolated fields of measured and derived parameters such as wind.

Sciences objectives of EMCS are to:

Enhance understanding of Mars photochemistry by providing daily, global, high vertical resolution fields of atmospheric state, aerosol distribution, and water vapor concentration. EMCS atmospheric state measurements, combined with data assimilation, characterize the transport, sources and sinks of trace gases measured by the proposed EMTGO. The aerosol measurements reveal the heterogeneous photochemical pathways of trace gases. EMCS plans to map water vapor, the key source gas for odd hydrogen, known to be important in Martian photochemistry.

Extend the MRO/MCS climatology of high vertical resolution measurements of the lower and middle atmosphere of Mars, with the improved coverage of local time provided by the proposed EMTGO. EMCS will determine the diurnal, seasonal & long-term variability of temperature and aerosol, and its impact on photochemistry. EMCS climatology, combined with earlier data, would relate EMTGO observations to earlier trace gas measurements.

Support future Mars missions with measured climatology and near real-time density profile retrievals for landing and aerocapture, in the same way that MRO/MCS supported the Phoenix landing and is supporting the Mars Science Laboratory (MSL) landing.

EMCS could be the only instrument in orbit able to support Entry, Descent and Landing (EDL) for the proposed ExoMars 2018 Rover Mission.

2. Instrument description

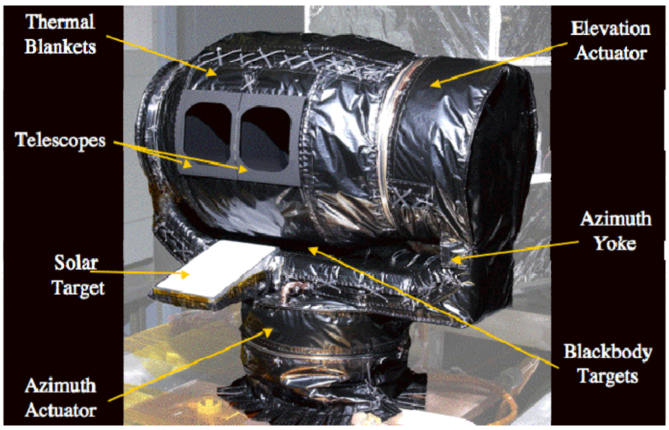

Figure 1 – The MRO/MCS instrument during thermal vacuum testing at JPL

EMCS is a copy of the Mars Climate Sounder (MCS) instrument on the Mars Reconnaissance Orbiter (MRO) spacecraft [1], with low impact modifications to 2 of 9 spectral filters and for interfaces with the proposed EMTGO spacecraft. MCS is now in its 5th year of returning atmospheric profiles from Mars [2]. EMCS is an infrared, limb sounding, filter radiometer which uses 9 spectral channels from 12 - 45 µm to address its measurement objectives. The 270° elevation/azimuth articulation of the instrument provides full coverage of the downward hemisphere allowing limb observations in all directions and giving daily, global, pole-to-pole coverage of Mars from the 74 ± 10° inclination EMTGO orbit. Uncooled, 21-element, linear thermopile arrays in each spectral channel are the enabling technology of EMCS, permitting atmospheric profiles to be derived from limb staring observations with better sensitivity and geometrical stability than limb scanning. By combining in-track limb and nadir observations, retrieved profiles could be extended to the surface over much of the planet.

Table 1 – The response and measurement function of the nine EMCS spectral channels.

Telescope/ Channel #	Bandpass cm^{-1}	Band Center - µm	Measurement Function
A1	595 - 615	16.5	Temperature 0-30 km
A2	615 - 645	15.9	Temperature 30-50 km, Pressure
A3	635 - 665	15.4	Temperature 50-90 km, Pressure
A4	820 - 870	11.8	Water ice extinction 0-90 km
A5	400 - 500	22.2	Dust extinction 0-90 km
A6	575 - 595	17.1	Temperature 0-15 km, CO_2 ice extinction 0-90 km
B1	290 - 340	31.7	Dust and ice extinction 0-90 km
B2	220 - 260	41.7	Water Vapor 0-40 km, Dust ice extinction 0-90 km
B3	231 - 243	42.2	Water ice extinction 0-30 km

Original MCS Channels
Substituted for visible channel to enhance temperature and CO_2 ice profile retrievals

Table 1 summarizes the coverage of the nine EMCS spectral channels, their distribution between the two instrument telescopes, and the primary measurement function of each channel. With the exception of A6, their functions are identical to those of MRO/MCS. A6 was a broad-band visible channel, designed for polar radiative balance measurements, which cannot be addressed from the 74° inclination proposed EMTGO orbit. It has been replaced by a spectral interval designed to improve low altitude temperature and CO_2 ice extinction profiling.

Measurements.

Based on the performance of MRO/MCS [3], and water vapor retrieval simulations, EMCS obtains atmospheric profiles with an accuracy of 1 - 2 K in temperature, < 0.0001 km^{-1} in aerosol opacity, and < 10 ppm (0.7 pr.µm) in water vapor mixing ratio, with 5 km vertical resolution and 0 - 90 km vertical coverage. This vertical resolution is necessary to resolve important atmospheric structure and to match the high vertical resolution trace gas measurements of the microwave and solar occultation instruments.

EMCS measurements are uniquely synergistic with the rest of the proposed EMTGO payload. They would provide daily global fields to supplement the more sparsely sampled solar occultations, and supply the dust and ice opacities. Furthermore, the articulation provided by the actuators allows coincident measurements with occultation, limb, and nadir sounding instruments regardless of their orientation on the spacecraft.

Figure 2 shows a nighttime pole-to-pole transect of combined limb-nadir retrievals from MRO/MCS for a single orbit. The dashed lines indicate the individual profiles, and their slope is due to the altitude dependence of tangent point location. Temperature profiles are retrieved up to ~90 km altitude with a typical precision between 0.5 and 2 K over most of this altitude range. Errors tend to be larger only at very high altitudes and very low temperatures. Pressure is retrieved to a precision of 1 - 2% at 20 - 30 km, and profiles of dust and water ice extinction achieve precisions of 10^{-4} - 10^{-5} km^{-1}.

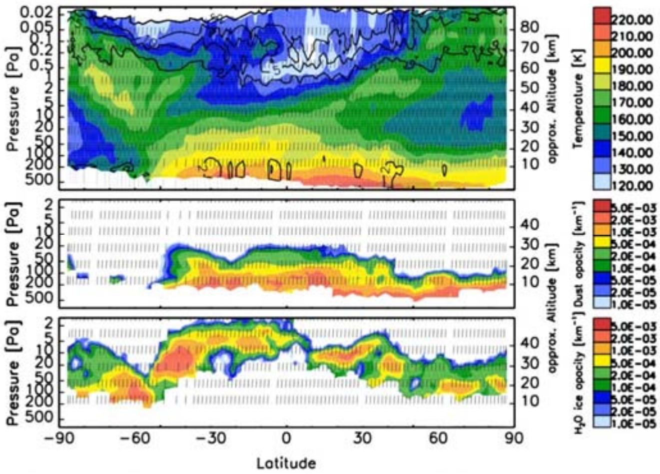

Figure 2 - Transect of MCS temperature (top), dust opacity (middle) and water ice opacity (bottom) retrievals for a single orbit at Ls = 155° (12/23/2006).

References

[1] McCleese, et al., 2007, Mars Climate Sounder: An investigation of thermal and water vapor structure, dust and condensate distributions in the atmosphere, and energy balance of the polar regions, *J. Geophys. Res.*, *112*, E05S06, doi:10.1029/2006 JE002790.

[2] McCleese, et al., 2008, Intense polar temperature inversion in the middle atmosphere on Mars, *Nature Geoscience 1*, 745-749.

[3] Kleinböhl, et al., 2009, Mars Climate Sounder limb profile retrieval of atmospheric temperature, pressure, and dust and water ice opacity, *J. Geophys. Res. 114*, E10006, doi:10.1029/2009JE003358