A Study of the Martian South Polar Cap Using EMIRS and TES data

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Introduction:

In July 2020, the Emirates Mars Mission (EMM) launched to Mars and successfully entered the planet's orbit by February 9, 2021.The Mission aims to gather information about the diurnal and seasonal dynamics of the whole planet's atmosphere (EMM, Amiri et al., 2022). There are three instruments on board EMM, which are the Emirates Mars Infrared Spectrometer (EMIRS), the Emirates Exploration Imager (EXI) and the Emirates Mars Ultraviolet Spectrometer (EMUS). The first two instruments capture information about the different constituents found in the lower atmosphere such as water vapor, ice clouds and dust among others to map out a three-dimensional global thermal structure. The third instrument (EMUS) is used to study the upper atmosphere in order to have a meaningful picture linking the lower atmosphere and the exosphere of Mars.

One notable characteristic of Mars is that the planet has polar ice caps comprised of carbon dioxide and H2O ice, which show a rise during fall and winter and a drop during the spring and summer.

Research Objective:

This research aims to investigate the planet's surface temperature at the polar caps by utilizing data captured by Thermal Emission Spectrometer (TES) (TES, Christensen et al., 2001) and EMIRS (Edwards et al. 2021 Space Science Reviews paper). A rough indication of whether the polar caps are covered with ice is the surface temperature, with observations of 150 K or less. The study focused on the South polar region as there is better coverage and more data is available on it through available observations.

Data and Tools:

One of the key instruments on the Mars Global Surveyor (MGS) is the TES, which is made up of six detectors that are aligned in a 2-by-3 formation. While the nominal spot size of the TES detectors is 3x6 kilometers during mapping, it could have much higher footprint because of the elliptical nature of its orbit when aerobraking. The instrument also has two channels: one is a broadband near-infrared bolometer while the other is a hyperspectral thermal infrared spectrometer. TES aerobraking spectra were taken between Mars Year 23, Ls=180° and Mars Year 24, Ls=30° and the geometry is calculated using Spacecraft Planet Instrument Camera Matrix and Event (SPICE) Toolkit to determine the footprint location on the surface.

Methodology:

One part of the analysis used for these data is the ringing correction technique, which helps to smooth and remove noisy data. Suppose the observed radiance (including the ringing) is in a vector "R", then we can remove ringing using: Rnew(i) = [0.25 * R(i-1) + 0.5 * R(i) + 0.25 * R(i+1)]. This 'smoothing' of the data in a mathematical method also known as convolution.

In this study we use Q = [0.25, 0.5, 0.25 and Rnew = conv (R, Q, 'same'). "Same" indicates matching the Rnew vector with the length of the R vector.

Another analysis step used in the research is binning using a moving boxcar average, which help identify any trends in the data collected. The binning process looks at results captured within an interval to be able to calculate the average value and plot it. This approach excludes the outliers, which is why considering the median is more useful that looking at the mean to minimize the outlier effect.

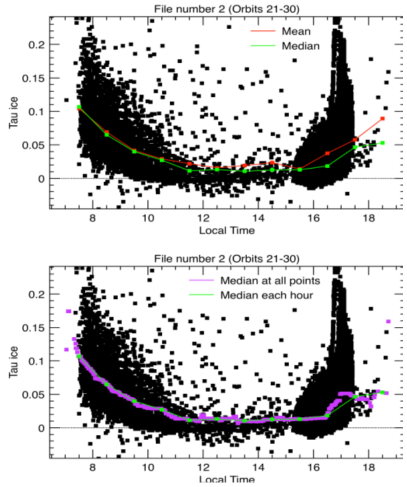

Figure1: Boxcar Technique

For the Mars pole's surface temperature if the emission angle is more than 70° then the spectrum was skipped since spectra at such high emission angles are only skimming the surface and can include large atmospheric effects. The latitude is the second factor, where the spectrum considered should be located poleward of -50° as the coordinates of the South Polar region considered here are within the latitudes from -90° and -50°. Moreover, the surface temperature was computed using the brightness temperature between 300 cm^{-1} and 500 cm^{-1}.

Results:
A series of polar-projection plots are made to see how the south polar cap changes with season. Same previous steps are applied to find surface temperatures and to show if the pole is covered by ice or not.

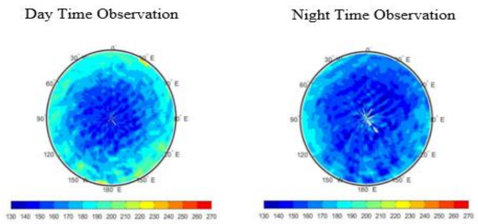

Figure2: Polar projections showing Surface Temperature from TES observations

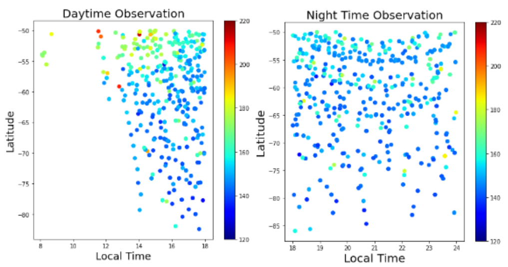

Figure3: Local Time-Latitude of Surface Temperature from EMIRS observations

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