Methodologies proposal for Mars' permafrost study using orbital and rover data

Molina, A.(1), de Pablo, M.A.(2)and Ramos, M.(3)

(1) Planetology and Habitability Department, Centro de Astrobiología (CSIC/INTA), 28850 Madrid, Spain, a.molina@csic.es
(2) Geology Department, Universidad de Alcalá, 28871 Madrid, Spain
(3) Physics Department, Universidad de Alcalá, 28871 Madrid, Spain

Key words: Mars, extraterrestrial permafrost, data processing

Mars is considered to have a wide spatial distribution of permafrost (e.g. Forguet et al., 2008) and it is a recursive research topic due to its astrobiology relevance, because it might be a probable habitat for microbial life (Cockell, 2008). It also has strategic importance for future human exploration and colonization since it could be a possible source of water supply, among other implications (structural, environmental, etc.). Our team has been working in recent years in studying the Martian permafrost by the use of available data from different planetary missions from NASA and ESA space agencies, applying our experience in studying and monitoring Antarctic permafrost. In Antarctica we are able to made in-situ measurements, setting up temperature sensors into boreholes and atmospheric monitoring sensor on surface. But in the case of Mars permafrost research, it is necessary to use the available data obtained by planetary exploration missions. These data sets are acquired by multiple sensors onboard orbiters or rovers (e.g. robotic vehicles) and they were published by sensors' teams and space agencies. Although these data are free to use, require complex processing and the permafrost nature is still uncertain. During the past two years we have developed some methodologies to analyze Martian data in order to study remotely the permafrost, obtaining interesting results. We focus on four approaches in this line (Figure 1):

To study surface temperature from brightness temperature derived from orbital data (THEMIS BTR).

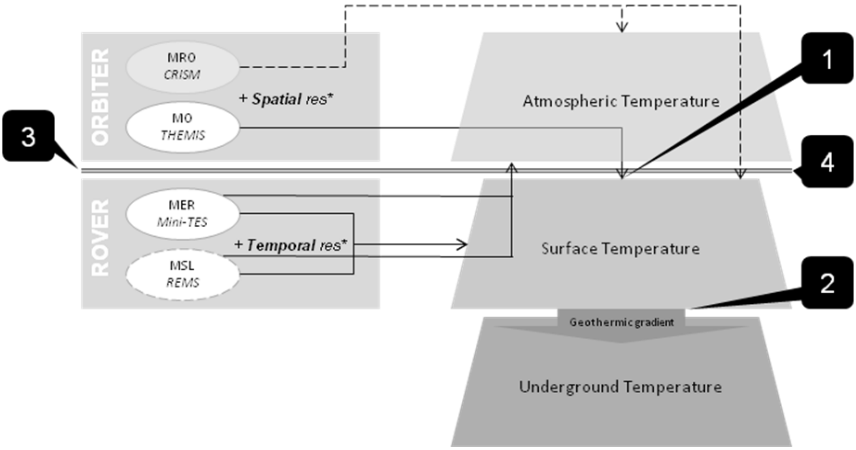

Figure 1: *Flowchart that represents the points in which our research of Martian permafrost has focused (numbers 1 to 4, explained in the text). On the left the sensors are shown, while the data are shown on the right. The double line represents the atmosphere.*

To estimate permafrost depth from THEMIS BTR (lineal gradient soil temperature distribution model) based on different geothermal gradients proposed in the bibliography.

To compare orbital data to those acquired by rovers (THEMIS vs. Mini-TES) and crossing data taken “at a time” from the surface and the atmosphere.

To study the annual variations in surface and atmospheric temperatures derived by Mini-TES data.

Firstly, (1) we begun analyzing the surface brightness temperature derived from data obtained by Thermal Emission

Imagining System (THEMIS) sensor, on board the 2001 Mars Odyssey orbiter. By processing the infrared THEMIS images it is possible to obtain the surface temperature. Then, comparing different overlapping THEMIS BTR images obtained at different times (dates and hours) it is possible to study the temperature range and the apparent thermal inertia of the surface (Fergason et al., 2006). Matching these surface temperature maps with Digital Terrain Models (DTMs) it is also possible to determine the influence of solar radiation incidence. Continuing along these terms, (2) we had made map algebra with geophysical equations. This allows estimating ground temperature based on surface temperatures taken on different dates and applying geothermal gradients proposed on literature (Molina et al., 2010 and references therein). With these procedures and the DTMs, the next step on the calculation on selected profiles of the differences between isotherms of 0ºC depth. These changes would be related to presence of active layer. Relating depth temperatures to topography is also useful for locating where liquid water could be shallower.

Orbital sensor offers information from a wide area but in a single time, while rovers provide spot information of where they are. Due to their low mobility rovers' data set contains information from temporal evolution for a relatively small region. So we started to work with (3) data acquired by Mini-TES instrument: a Thermal Emission Spectrometer onboard the Spirit rover, one of the twin vehicles of Mars Exploration Rover mission. We took data for the same place and time for THEMIS and Mini-TES, and we found that the data range is quite similar, with differences that we attribute to the interference of the atmosphere and dust in suspension. (4) Rovers can also provide atmospheric temperature. The relevance on soil-atmosphere interface makes really interesting incorporates these data in our study. In the case of Mini-TES instrument its orientation allows to provide surficial temperatures when "looks down" or atmospheric temperatures when "looks up". We focused in surface and atmospheric temperatures annual variations, trying to find behavior patterns in temperature evolution along the Martian year. On this aspect we highlighted the clear sinusoidal wave year trend, where surficial values are more dispersed than atmospherical. This is probably owed to soil is a more heterogeneous media than air (even with dust). It is also interesting to note that air-soil differences are lower on the second half of Martian year.

In the future we plan to incorporate data provided by the next NASA's rover from Mars Science Laboratory (MSL) mission. This mission includes the Rover Environmental Monitoring Station (REMS), an instrument designed to record air and ground temperature, among four other atmospheric parameters (wind speed/direction, pressure, relative humidity and ultraviolet radiation; Gómez-Elvira, 2011). We look forward to apply the methodologies here showed to REMS data, and get characterize the possible permafrost under the not yet determined landing site.

References

Cockell, C. (2008) Is microbial life on Mars possible? Microbiology today 35, 66-69.

Fergason, R. L., Christensen, P. R. and Kieffer, H. H. (2006), High-resolution thermal inertia derived from the Thermal Emission Imaging System (THEMIS): Thermal model and applications, J. Geophys. Res., 111, E12004, doi:10.1029/2006JE002735.

Forget, F.; Costard, F.; Lognonné, P. (2008). Planet Mars, Story of another world. Berlin (Alemania): Springer – Praxis. ISBN: 978-0-387-48925-4.

Gómez-Elvira, J., Haberle, B., Harri, A., Martinez-Frias, J., Renno, N., Ramos, M., Richardson, M., de la Torre, M., Alves, J., Armiens, C., Gómez, F., Lepinette, A., Mora, L., Martín, J., Martín-Torres, J., Navarro, S., Peinado, V., Rodríguez-Manfredi, J.A., Romeral, J., Sebastián, E. J. Torres, Zorzano, M.P., Urquí, R., Moreno, J., Serrano, J., Casta, L., Jiménez, V., Genzer, M. and Polko, J. (2011) Rover Environmental Monitoring Station for MSL mission. 4th International workshop on the Mars Atmosphere: modeling and Observations. Feb 8-11. París, France.

Molina, A., de Pablo, M.A. and Ramos, M. (2010) Studying Martian permafrost from surface temperature data of Mini-TES, Spirit MER mission. In: Ambientes periglaciares, permafrost y variabilidad climatic. Blanco, J.J., de Pablo, M.A., Ramos, M. UAH Obras colectivas, Ciencias 06, 197-204. Alcalá de Henares, España. ISBN: 978-84-9138-885-5.