

Comparison of the Martian thermospheric density and temperature from IUVS/MAVEN data and general circulation modeling

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The Mars Atmosphere and Volatile Evolution (MAVEN) Mission, which operates for slightly over one year to date, has been specifically designed for investigating the upper atmosphere. The Imaging Ultraviolet Spectrograph (IUVS) onboard MAVEN measures spectra of mid- and far UV atmospheric emission, which are used for retrieving vertical density profiles of CO₂ and other species. Newly released IUVS/MAVEN measurements of CO₂ density in the Martian thermosphere have been used for comparison with the predictions of the Max Planck Institute Martian General Circulation Model (MPI-MGCM). In this study, we focus on the October 2014 campaign in which a total of 122 density profiles were obtained for the period between 18 and 22 October (Ls=216.68-218.94). IUVS nicely covers the thermosphere in the altitude range of 130-220 km. The MGCM demonstrated the sensitivity of simulated density and temperature profiles on (i) solar flux, (ii) atomic oxygen, and (iii) small-scale gravity waves (GWs). It is the only MGCM to date that includes a parameterization of effects of subgrid-scale GWs with broad spectra.

The simulations reproduced (within one standard deviation) the available zonal mean density and derived temperature above 130 km. The comparison shows a great role of gravity waves in the thermosphere, and in bringing the simulated density and temperature closer to observations. The MGCM replicated the observed dominant zonal wavenumber-3 non-migrating tide, which was already reported by MAVEN measurements (Lo et al., 2015). The simulations also demonstrated that it represents a non-moving imprint of the topography in the thermosphere.

This comparison confirms that, with the current state of knowledge of the Martian thermospheric physics, MGCM can reproduce its state and variability. Further observations will help to constrain physical parameterizations and improve modeling capabilities.

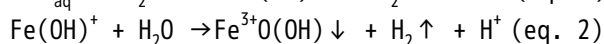
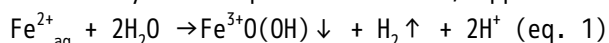
Keywords: Gravity waves, Tides, MAVEN

Runaway acidification on early Mars triggered by atmospheric evolution

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Mineralogical and chemical observational data of sedimentary rocks deposited on early Mars suggest that chemistry of Mars' surface water had shifted from neutral pH (pH~7-9) to highly acidic (pH~2) at around 3.5 billion years ago (Ga) (Bibring et al., 2006; Ehlmann et al., 2011). One proposed mechanism for this acidification is photo-oxidation of ferrous iron dissolved in surface water (Hurowitz et al., 2010). When UV light is irradiated to surface water, ferrous iron are oxidized to ferric iron by producing H⁺ with precipitation of Fe³⁺ minerals (see Equations 1 and 2 below). Hurowitz et al. (2010) show that H⁺ produced via this mechanism are quantitatively sufficient to explain the mineralogical and chemical compositions of sedimentary rocks in Meridiani Planum observed by Mars Exploration Rover, Opportunity (e.g., Tosca et al. 2005).



Although this mechanism would have promoted acidification at 3.5 Ga on Mars, it remains unsolved why surface water with neutral pH had been maintained before 3.5 Ga, and what the trigger for the acidification was. In this study, we propose a new hypothetical scenario to explain the chemical transition of surface water from neutral to acidic pH by considering positive and negative feedbacks in association with photo-oxidation of ferrous iron.

Ferrous iron has two stable dissolved species; Fe²⁺ and Fe(OH)⁺, depending on pH of water. It has been reported that both species are oxidized when irradiated with UV (< 200 nm). But, Fe(OH)⁺, which becomes the dominant species at pH > 9, is also oxidized with irradiation of visible light (300-400 nm) (Braterman et al., 1983). In a thick CO₂ atmosphere (~1 bar) with several ppms of SO₂, UV light with short wavelength (< 300 nm) is shielded by the atmospheric gas species. In this case, photo-oxidation of Fe(OH)⁺ proceeds in surface water, whereas that of Fe²⁺ is limited. In surface water with neutral to alkaline pH, photo-oxidation of Fe(OH)⁺ acidifies the water forming H⁺. However, the concentration of Fe(OH)⁺ drastically decreases around pH~6.5 via the conversion into Fe²⁺. This decrease in Fe(OH)⁺ concentration, in turn, results in dampening Fe(OH)⁺ photo-oxidation. Consequently, in a thick atmosphere, pH dependence of Fe(OH)⁺ photo-oxidation works as a negative feedback to maintain surface water pH around neutral.

On the other hand, in a thin CO₂ atmosphere (0.1 bar or less) with < 1 ppm of SO₂, UV light reaches to the surface water, leading to photo-oxidation of both Fe²⁺ and Fe(OH)⁺ in surface water. In this case, even if the concentration of Fe(OH)⁺ in surface water decrease at pH~6.5, acidification proceeds via photo-oxidation of Fe²⁺. As a result, a runaway acidification to highly acidic surface water occurs via this positive feedback.

Here, we discuss the above possibility more quantitatively using the previous laboratory data on photo-oxidation rates of Fe²⁺ under acidic conditions by Jortner et al. (1962) and those by Braterman et al. (1983) under neutral pH conditions. We calculate the total production rate of H⁺ both via the photo-oxidation of Fe²⁺ and Fe(OH)⁺ for various atmospheric compositions and pressures. Based on our sensitivity study of the abundances of CO₂ and SO₂ to acidification of surface water, the critical atmospheric compositions to drive the runaway acidification are discussed.

Keywords: Mars, acidification, atmospheric evolution, photooxidation, geochemistry

Warmer Wetter Mars in the Past?

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The isotopes of CO₂ (¹³C/¹²C, ¹⁸O/¹⁶O), H₂O (D/H), N₂ (¹⁵N/¹⁴N), Ar (³⁸,⁴⁰Ar/³⁶Ar), Kr and Xe are excellent indicators of climate change in the atmosphere of Mars. Recent high precision measurements of those isotopes with the quadrupole mass spectrometer and the tunable laser spectrometer of the Sample Analysis (SAM) suite of instruments on the Curiosity Rover clearly show that the atmosphere of Mars has been substantially depleted over the past four billion years. At the same time, both geological evidence and a comparison of the D/H isotope ratios in water vapor in the atmosphere with the Hesperian-era Gale Crater smectite rock fines, and even older Mars meteorites suggest a relatively large abundance of (liquid) water on the surface of Mars in the past. With the exception of xenon, the above isotopes inform about the change since roughly 4 Ga. The isotopic fractionations in xenon suggest, in addition, a massive H₂-driven hydrodynamic escape very early in the geologic history of Mars. Employing the isotopic record in the atmosphere and rock fines, we investigate a scenario of Mars where atmospheric composition and relatively high atmospheric pressure resulted in warmer conditions necessary for maintaining surface liquid water at least intermittently through late Noachian/early Hesperian, followed by a gradual loss of the atmosphere by escape since then, hence warmer and wetter conditions in the past compared to Mars' present cold and arid state.

Keywords: Mars, Climate Evolution, Isotopes

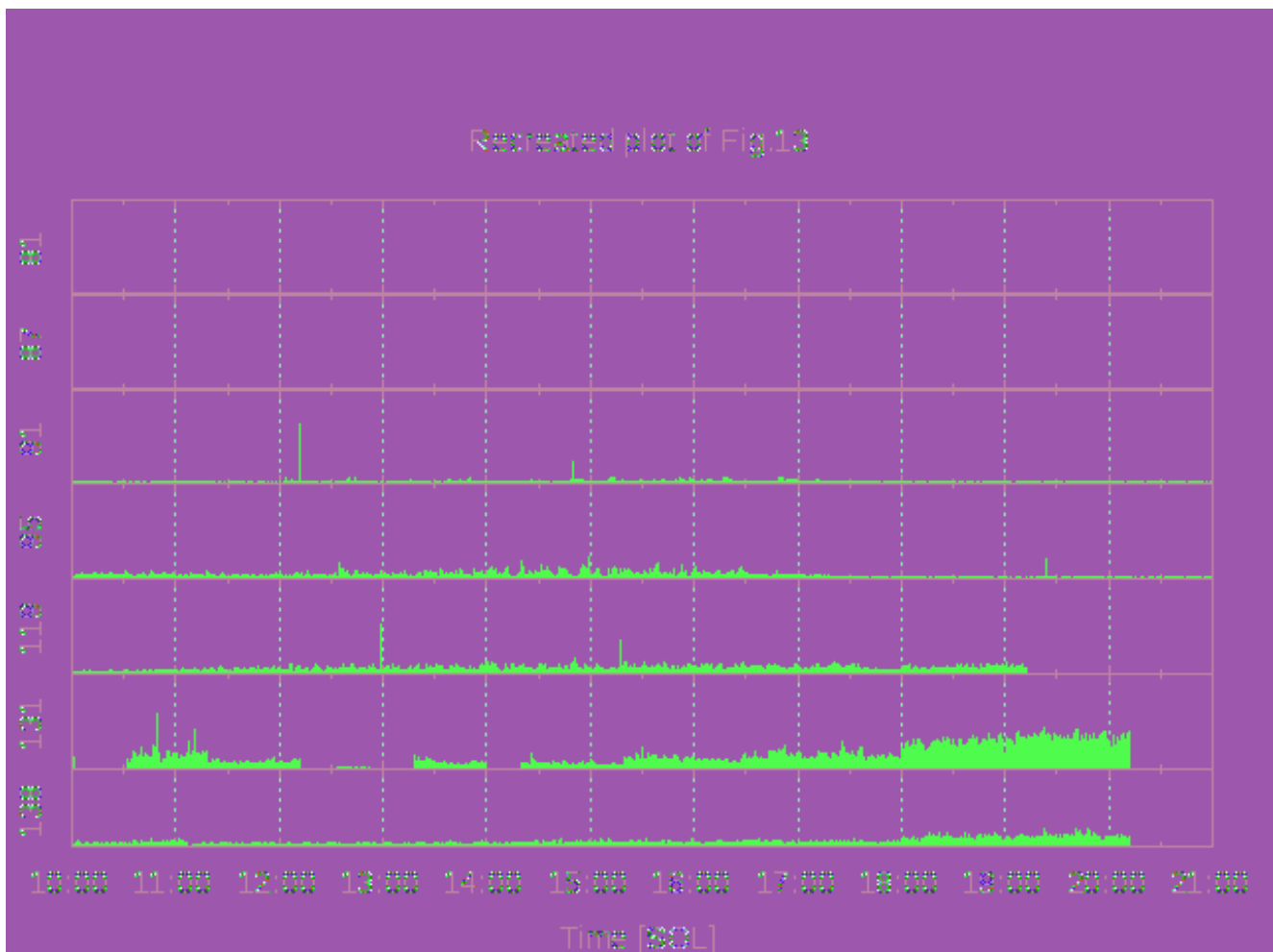
Current status of data restoration of the seismometer onboard Viking Lander 2

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The Viking Lander 2 launched in 1975 carried a seismometer to the Mars. Even after 40 years later, the data obtained by the seismometer is only seismic data from the Mars. The data showed there was no evidence of seismic events on the Mars. The data had not been archived properly for a long time, and it was difficult to verify for other scientists. We had tried to perform the data restoration, and some figures in an old report could be restored. After applying the restoration to all data, the original data contained some fatal errors. Therefore, it is difficult to conduct scientific analysis using these data. The purpose of this study is to provide new dataset overcoming these errors.

Keywords: Viking, Seismometer, data



Analysis of microphones operating characteristics under harsh environment in order to develop a sound detector in Martian atmosphere

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Introduction: In 2020s, launches of a Japanese Mars explores are planned by Japan Aerospace Exploration Agency (JAXA), and realization of the series-like Mars explorations is expected. As of 2016, the sonic wave observation in Martian atmosphere has never been carried out. Not only measuring Martian atmospheric sound with the dust events but also sensing of physical parameters in Martian atmosphere could be realized if a few small microphones are equipped on a Rover for exploration based on an appropriate design and development.

Purpose: We perform microphone testing experiments under simulated severe Martian environment by using vacuum chambers in order to select one from two kinds of microphone Breadboard models (BBM), capacitor type microphones and Micro Electro Mechanical Systems (MEMS) type ones experimentally. Under the assessment process, enhancement of detection performance with applying the microphone array is evaluated under the simulated Martian atmospheric conditions.

Experiment outline: An atmospheric condition with 95% of CO₂ component occupies with its atmospheric pressure level of 7 hPa as well as temperature level of -120 degree Celsius like nighttime Martian surface was used for simulating severe environment in the experiment at Chiba Institute of Technology in January, 2015. Furthermore, We performed a calibration experiment of microphone BBMs in Kochi University of Technology. We call the sound less than 20 Hz that is the lowest limit of the audible sound as the infrasound. Aiming at successful detection of the infrasound signal in the Martian atmosphere in future, we input simulated infrasound signal with audible range sound into the experimental space as calibration basis. Here, we use a vacuum chamber as a rigid container for performing repeated compression/absorption with a small syringe as a small volume with periodically creating slight atmospheric pressure waves as an exact wave pattern. We assumed this process can make a wave pattern of infrasound for calibrating the microphone BBMs. Evaluation of a Chaparral Physics Model25 infrasound sensor and microphone BBMs was carried out with simulating 0.1 Hz infrasound with 1 Pa amplitude.

Experimental result: The result of a measurement using the simulated infrasound signal provided a clear spectrum peak of 0.1 Hz frequency with the both sensors. The capacitor type microphone have effective precision better than the infrasound sensor at the 0.1 Hz range. We compared the MEMS microphones with the capacitor microphones under the same condition. The capacitor microphones could clearly detect infrasound of 0.1 Hz, but seldom detectabilities for the MEMS microphones.

Conclusion: Under the simulated severe Martian atmospheric environment, we compared the performance of capacitor and MEMS microphones, resulting in an advantage of the capacitor type microphones suitable for sensing in the Martian atmosphere. We conclude that the capacitor type microphones should be selected for detecting infrasound signal at around 0.1 Hz for Martian exploration.

Keywords: Mars, Infrasound

LDM (Life Detection Microscope): In situ imaging of living cells on surface of Mars

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Past trial of detection of life on Mars by 1970's Viking mission ended up with a negative conclusion [1]. Whereas, numbers of new finding provided by Mars exploration missions in the last decade indicate that there are good reasons to perform another life detection program. The sensitivity of GC-MS onboard the Viking mission was not very high, and was not able to detect the microbes 10^{**6} cells in 1 gram clay [2,3]. Here we propose Life Detection Microscope (LDM) that has much higher sensitivity than the instrument onboard Viking.

Resent observations on Mars have found the evidences of past water activities. MSL Curiosity has reported the temporal increase of methane concentration in Martian atmosphere [4]. The presence of reduced sulfur compound such as pyrite in Martian soil was also detected by MSL [5]. Methane and reduced sulfur compound can be the energy source to support the growth of chemoautotrophic microbes [6]. Possible presence of liquid water at Recurring Slope Lineae has been supported by the detection of hydrated salts [7]. The presence of organic compounds of Martian origin has been reported [8]. These evidences tend to support the possible presence of living microbes near the surface of Mars.

Physical and chemical limits for terrestrial life have been major foci in astrobiology [9], and are summarized in ref. [6]. Combining the environmental factors, anywhere in the Martian environment where we can find the three components, water molecules, reducing compounds and oxidative compounds could be an environment where life can be sustained for long periods of time, if other factors such as temperature, pressure, UV and other radiations permit [6]. Among these factors, most of the factors including ionic radiation, can be endured by terrestrial extremophiles. Only UV can kill the most UV-resistant microbes within minutes. However, UV can be shielded by a-few-centimeter sail layer. These evaluation lead to the conclusion that the Martian soil under a few cm can be the place to support the growth of microbes, if the water activity is higher than 0.6.

We will report the current status of the development of the LDM. We propose to search for cells from a depth of about 5 - 10 cm below the surface, which is feasible with current technology. Microscopic observation has the potential to detect single cells. We have developed the solution and combination of fluorescence pigments to detect organic compounds, and to differentiate organic compounds surrounded by membrane. The subsequent analysis of amino acids, in the following mission, will provide the information needed to elucidate the origin of the cell.

LDM that we propose here could detect less than 10^{**4} cells in 1 gram clay [6]. LDM is capable of identifying what we think to be the most fundamental features that a cell should possess to constitute life. Our Investigation Goals are the followings. 1) Identify cell-like structure in which organic compounds are enveloped by membrane, which may represent Martian life. 2) Search for any type of organic compounds in Mars surface samples. The compounds include cells, other biological materials, and abiotic polycyclic aromatic hydrocarbon (PAH). 3) High-resolution characterization of regolith and dust particles.

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Keywords: Mars, Fluorescence microscope, Life search

Tracking the MSL-SAM methane detection source location Through Mars Regional Atmospheric Modeling System (MRAMS)

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The putative in situ detection of methane by SAM instrument has garnered significant attention. There are many major unresolved questions regarding this detection: 1) Where is the release location? 2) How spatially extensive is the release? 3) For how long is CH₄ released? In an effort to better address the potential mixing and remaining questions, atmospheric circulation studies of Gale Crater were performed with the Mars Regional Atmospheric Modeling System (MRAMS). The model was focused on rover locations using nested grids with a spacing of 330 meters on the innermost grid that is centered over the landing. MRAMS is ideally suited for this investigation. In order to characterize seasonal mixing changes throughout the Martian year, simulations were conducted at Ls 0, 90, 180 and 270. Two additional simulations at Ls 225 and 315 were explored to better understand the unique meteorological setting centered around Ls 270. Ls 270 was shown to be an anomalous season when air within and outside the crater was well mixed by strong, flushing, northerly flow and large amplitude breaking mountain waves: air flowing downslope at night is cold enough to penetrate all the way to the surface. At other seasons, the air in the crater is more isolated -but not completely- from the surrounding environment: mesoscale simulations indicate that the air flowing down the crater rims does not easily make it to the crater floor. Instead, the air encounters very cold and stable air pooled in the bottom of the crater, which forces the air to glide right over the colder, more dense air below. Thus, the mixing of near surface crater air with the external environment is potentially more limited at seasons other than around Ls 270. The rise in CH₄ concentration was reported to start around sol 300 (~Ls 336), peaked shortly after sol 520 (~Ls 82), and then dropped to background values prior to sol 575 (~Ls 103). Two scenarios are considered in the context of the circulations predicted by MRAMS. The first scenario is the release of methane from somewhere outside the crater. The second is a release of methane within the crater. In both cases, the release is assumed to take place near the season when the rise of concentration was first noted (~Ls 336). This is a transitional time at Gale Crater, when the flushing winds are giving way to the more isolated crater scenario. Some preliminary work, including tracer gases into the model, is being performed to establish the amount of mixing during the limited mixing epochs. Preliminary results may support the idea that during periods of limited mixing, there could be enough time for methane to bind to activated mineral surfaces through wind erosion.

Keywords: Mars meteorology, Mars atmosphere, Mars Science Laboratory, Gale crater, methane

Distribution of phyllosilicates on Utopia Planitia, Mars

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Many studies suggest that abundant liquid water existed in the past on the Martian surface, although there is currently no liquid water on the surface of Mars. The hydrated minerals are generally formed through long-term contact with water or alternation by water. We can get a key to understand the water environment of Mars by studying the observed hydrated minerals.

The wider distribution of hydrated minerals on the southern hemisphere on Mars has been reported in previous studies [e.g. Carter et al., 2013], however, only a limited number of outcrops of hydrated minerals are detected so far in the northern lowlands. The surface of northern lowlands is basically young being covered with lava materials in Hesperian through Amazonian ages. We expect that the deposition below the younger crust of the northern lowlands should host hydrated minerals commonly. The purpose of this study is to examine the distribution of hydrated minerals in the northern lowlands of Mars.

We focus on the comparatively larger craters which should expose the subsurface minerals by impact gardening in the northern lowlands of Mars. Our analysis targets are the craters with diameters ≥ 10 km in Utopia Planitia ranging 25-50N, 90-140E. The number of the craters amounts to 14 in total. We used the data from CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) onboard Mars Reconnaissance Orbiter. The spectral data cover near-infrared wavelengths. We tried to detect the absorption features characteristic to the phyllosilicates. We used CAT (CRISM Analysis Toolkit) combined with ENVI spectral analyst tool to analyze the latest CRISM data observed in the study area in detail.

As a result, phyllosilicates-bearing minerals were detected at 5 impact craters among 14 impact craters examined in this study. The 5 craters are: 2 craters where phyllosilicate hadn't been detected by Fairén et al. [2012], 2 craters not examined so far and 1 crater where phyllosilicates are already detected by Fairén et al. [2012]. The four kinds of phyllosilicates were detected: illite, smectite, vermiculate and a small number of saponite. We saw no discrete distribution according to the kind of minerals but we found that the distribution of phyllosilicates-bearing minerals strongly connects with erosional areas. We observed that phyllosilicates distribute at the rim, wall, floor, ejecta and around the central peak of the craters. These detected phyllosilicates are interpreted that deposited under the younger crust of the northern lowlands are emitted on the surface by impact gardening by Carter et al. [2010].

The number of samples in this study is still small, but the detection ratio of phyllosilicates seems significantly larger than Carter et al. [2013]. The results imply that hydrated minerals are possibly more widespread in the northern lowlands of Mars. Such detailed examination that uses the latest observation data and smart tools should result in increasing ratio of detecting phyllosilicates and contribute to clarification of water environment in the northern lowlands of Mars.

Keywords: Mars, hydrated minerals, phyllosilicate, infrared spectra, CRISM/MRO

High resolution Large eddy simulation on Martian planetary boundary layer

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A large-eddy simulation (LES) on Martian planetary boundary layer has been performed to examine structure and characteristics of turbulence in the layer and their dependency on experimental resolution. SCALE-LES, which is an LES model for large domain and high resolution experiments developed in RIKEN AICS (<http://scale.aics.riken.jp/>), is used in this study. Spatial resolution is swept from 100m to 5m. Domain size is about 20km in horizontal and vertical. Horizontal boundary condition is double periodic condition. Heating rate calculated by an offline one-dimensional experiment (Odaka et al. 2001) is used instead of explicit calculation of the radiative transform process.

Well-known features of the boundary layer, such as hexagonal structure of convective cells and the -5/3 energy spectrum, are reasonably simulated. Dependency of several physical quantities at 14:00-15:00 local time, when the boundary layer is almost mature, on the resolution is analyzed. We found that vertical heat flux and variance of vertical velocity of resolved component show convergence or systematic tendency with the resolution. Convective vortices are developed and most of them are located near the upward reasion.

Keywords: Martian Planetary Boundary Layer

Longitudinal dependence of CO₂ supersaturation during northern winter in the Martian atmosphere

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Using the temperature profiles of MGS radio occultation measurements (1998-2007), we show the strong longitudinal dependence of CO₂ supersaturation during northern winter in the Martian high-latitude (60-80N) atmosphere. The CO₂ supersaturation appears more frequently in the longitudes of 90-180E and 270-360E at the pressure levels of 400-30 Pa. The areas of CO₂ supersaturation overlap with zonal temperature minima.

Keywords: Mars, supersaturation, CO₂