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 Fe^{3+} 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).

$Fe^{2+}_{aq} + 2H_2O \rightarrow Fe^{3+}O(OH)\downarrow + H_2\uparrow + 2H^+$ (eq. 1)

$Fe(OH)^+ + H_2O \rightarrow Fe^{3+}O(OH)\downarrow + H_2\uparrow + H^+$ (eq. 2)

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; Fe^{2+} 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 CO_2 atmosphere (~1 bar) with several ppms of SO_2, 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 Fe^{2+} 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 Fe^{2+}. 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 CO_2 atmosphere (0.1 bar or less) with < 1 ppm of SO_2, UV light reaches to the surface water, leading to photo-oxidation of both Fe^{2+} 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 Fe^{2+}. 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 Fe^{2+} 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 Fe^{2+} and $Fe(OH)^+$ for various atmospheric compositions and pressures. Based on our sensitivity study of the abundances of CO_2 and SO_2 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 CO_2 ($^{13}C/^{12}C$, $^{18}O/^{16}O$), H_2O (D/H), N_2 ($^{15}N/^{14}N$), Ar (^{38},$^{40}Ar/^{36}Ar$), 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 H_2-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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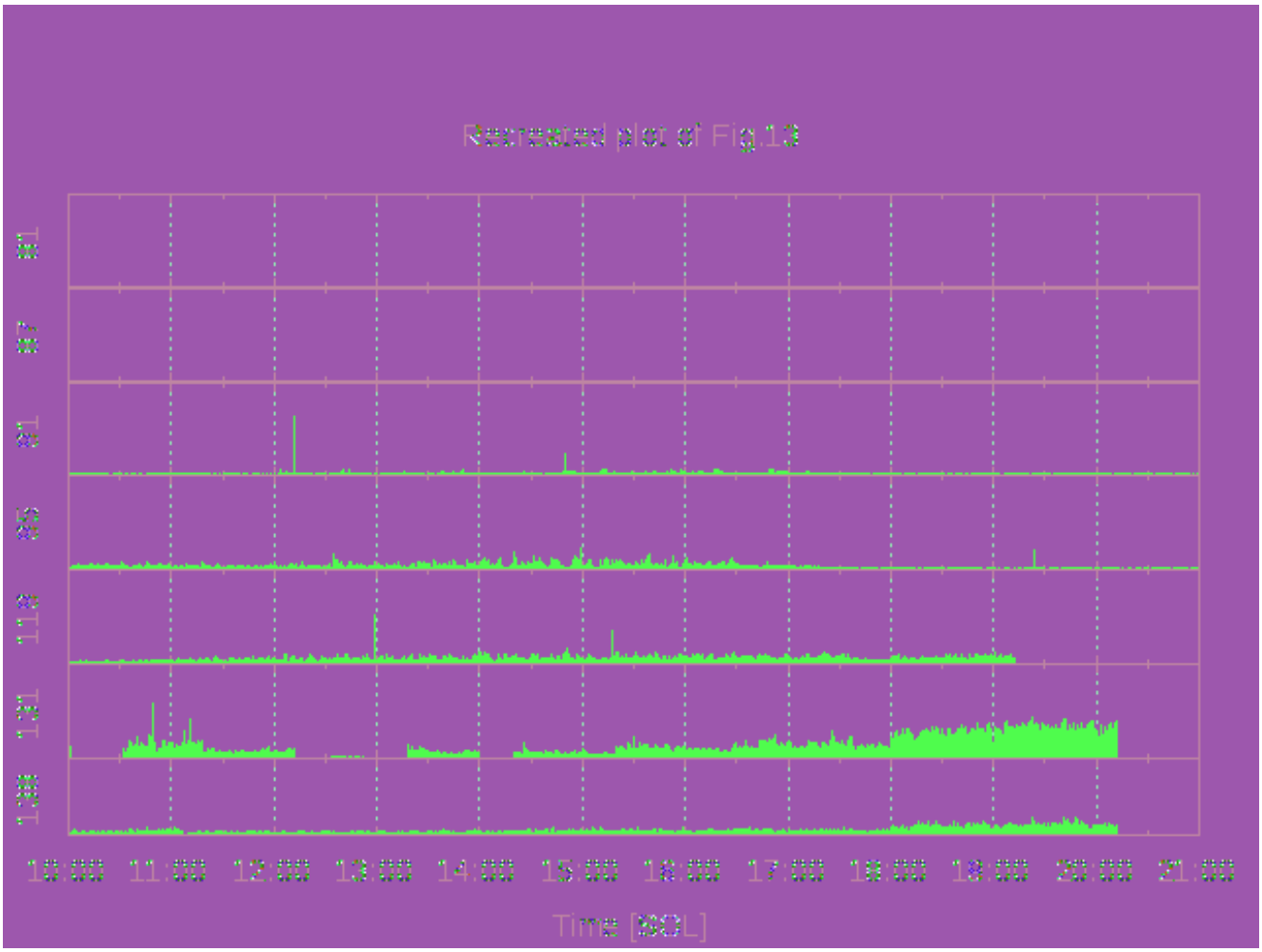
The Viking Lander 2 launched in 1975 carried a seismometer to the Mars. Even after 40 years later, the data obtained by the seismometer is only seismic data from the Mars. The data showed there was no evidence of seismic events on the Mars. The data had not been archived properly for a long time, and 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 atomosphere

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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 CO_2 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 ok 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 an 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 ≥ 10km 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 phyllisilicates 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 phyllosillicates 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 CO_2 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 CO_2 supersaturation during northern winter in the Martian high-latitude (60-80N) atmosphere. The CO_2 supersaturation appears more frequently in the longitudes of 90-180E and 270-360E at the pressure levels of 400-30 Pa. The areas of CO_2 supersaturation overlap with zonal temperature minima.

Keywords: Mars, supersaturation, CO2

Numerical simulation of water cycle in a Martian atmosphere by the use of a planetary atmosphere general circulation model, DCPAM

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Spacecraft observations of Mars revealed distributions of water vapor and water ice cloud in the Martian atmosphere. Those observations covered an almost global region and a long period. For example, the Mars Global Surveyor (MGS) observed column densities of water vapor and water ice cloud for about 9 Martian years. The MGS observation characterizes the seasonal variation of the water distribution in the Martian atmosphere. On the other hand, general circulation models (GCMs) have been used to investigate water cycle in the Martian atmosphere. Those models represented distributions of water vapor and water ice cloud consistent with observed ones, successfully.
In our group, we have been developing an atmosphere GCM, DCPAM, which is applicable to planetary atmospheres. By the use of the DCPAM, we have been performed simulations of Martian atmosphere without water cycle. In this study, the simulations of water cycle in the Martian atmosphere are performed by implementing relevant processes in the DCPAM. By performing the simulations, features of water cycle in the Martian atmosphere will be investigated and the model will be validated under a condition of Mars.
The DCPAM used in this study consists of a dynamical core based on the primitive equation system and physical processes relevant to Martian atmosphere. The dynamical core solves the primitive equation system by the use of spectral transform method with the finite difference method in vertical direction. The included physical processes are the radiation, the turbulent mixing, the surface processes, the CO2 and H2O condensation, and gravitational sedimentation. In the model, the radius of cloud particles is assumed to be a constant. By the use of a "Mars mode" of this model, several experiments have been performed. In the experiments, the dust distribution in the atmosphere is prescribed. In the vertical direction, the Conrath-type distribution is assumed. In the horizontal direction, the optical depth is prescribed following observations. In order to simulate water cycle, large amount of water ice is placed north of 80N. Further, the surface temperature south of 85S is fixed to 145 K to represent a permanent CO2 ice cap. Those H2O and CO2 ices at southern and northern high latitude regions act as source and sink of the water. The resolutions used for this study is T21L36, which is equivalent to about 5.6 degrees longitude-latitude grid and has 36 vertical levels. Under these conditions, the model is integrated for 10 Mars years from an initial condition of isothermal atmosphere at rest. The result during the last Martian year is analyzed.
The model is evaluated by comparing the column densities of water vapor and water ice cloud simulated by the model with those observed by the MGS. The simulations with ice cloud radius of 7 micron meter show following features of seasonal variation of those values which are roughly consistent with observations. From northern summer to northern fall, the water vapor is transported from northern cap to low latitude. At the same time, water ice cloud forms in northern low latitude where the ascending motion of Hadley circulation occurs. However, the low latitude water ice cloud from northern winter to northern spring is slightly thicker in the model than observed one. This may be caused by crude treatment of ice cloud in the model. In the presentation, features of water cycle represented in the model will be presented in more details.

Keywords: planetary atmosphere, general circulation model, Mars, water cycle

Diagnostic experiments of lifted dust flux at the surface with Mars GCM: Consideration of the effects of topography

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The Martian dust influences atmospheric thermal structure (e.g. Liu et al., 2003). Some research groups have made efforts simulating the Martian dust cycle with general circulation models (e.g. Newman et al., 2002, Basu et al., 2004, Kahre et al., 2006). We also implemented two dust lifting schemes into DCPAM (Takahashi et al., 2014) which is a general circulation model developed by our group: One is the lifting scheme with model resolved wind stress, and the other is the scheme with model unresolved vortices such as dust devils. And, we performed diagnostic experiments of the lifted dust flux with these schemes (Ogihara et al., 2014). Characteristics of the lifted dust flux of this result are roughly consistent with those of previous studies. But, because the behavior of dust lifting schemes is complex due to topography, we could not completely understand how the lifted dust flux distribution is decided. In order to understand effects of topography on the behavior of the dust devil lifting scheme, in the work we perform two diagnostic experiments of dust lifting with the flat topography and zonal mean topography. And, we compare the results of the experiment used the flat topography with those of used the zonal mean topography.
The model utilized is DCPAM. DCPAM adopts three dimensions primitive equations. The radiative scheme by Takahashi et al.(2003, 2006) is used. This includes the radiative effects of gaseous CO2 and dust. And, dust distribution is spatially and temporally fixed. The turbulent process is expressed by using vertical diffusivity based on Mellor and Yamada (1982). The surface process is expressed based on Beljaars and Holtslag (1991), Beljarrs (1994). We employ a dust devil lifting scheme used by Newman et al. (2002). This scheme calculates the lifted dust flux intensity with the surface sensible heat flux and the thermodynamic efficiency, which depends on the depth of the convective layer. The horizontal discretization is the spectral method, and the truncation wavenumber is 21. The vertical discretization is the finite difference method, and the number of levels is 36. We integrate 4 Mars years, and use the last 1 Mars year for analysis. We investigate about two regions: latitude 25N degree and 25S degree. And, we focus on the season during the spring and summer in each hemisphere, when dust is intensely lifted. We perform two diagnostic experiments of the lifted dust flux with fixed a surface distribution of thermal inertia and albedo. One is the experiment with flat topography (Case F) and the other is with zonal mean topography (Case Z).
First, results for regions around 25N degree are as follows. The zonal mean lifted dust flux of Case Z is smaller than that of Case F. Thermal budget analyses show that the heating the upper layer due to the convective adjustment of Case Z is less effective and meridional circulation is weaker as compared to Case F. So, the lower atmosphere of Case Z is more stable than that of Case F and the surface sensible heat flux of Case Z is less intensive than that of Case F. Therefore in Case Z the dust devil lifting is less active than that in Case F.
Second, results for regions around 25S degree are as follows. The zonal mean lifted dust flux of Case Z is greater than that of Case F. Thermal budget analyses show that the heating the upper layer due to the convective adjustment of Case Z is more effective and meridional circulation is more intensive as compared to Case F. So, the lower atmosphere of Case Z is more unstable than that of Case F and the depth of the convective layer of Case Z is larger than that of Case F. Therefore in Case Z the dust devil lifting is more active than that in Case F.

These results indicate that if the convective adjustment heats the upper layer and meridional circulation enhances, the dust devil lifting intensify.
In the future, we will investigate what does observed topography effect on the dust devil lifting.

Keywords: Mars, Dust, General Circulation Model, Dust Devil, Dust lifting

Assessment of the generation and propagation of the gravity waves in the Martian atmosphere using a high-resolution general circulation model

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Gravity waves (GWs) are small-scale atmospheric waves generated by various geophysical processes, such as topography, convection, and dynamical instability. On Mars, several observations and simulations have revealed that GWs strongly affect temperature and wind fields in the middle and upper atmosphere. Our previous study using the Max Planck Institute Mars General Circulation Model (MGCM) and the nonlinear spectral whole atmosphere parameterization of small-scale GWs by Yigit et al. [2008] have shown that the dynamical forcing of GWs significantly change the winds, reversing its direction above ~100 km [Medvedev et al., 2011]. We also have shown that the thermal effects induced by GWs can be the main source of cooling above ~120 km, reproducing the observed temperature structure on Mars [Medvedev and Yigit, 2012]. Similar physical importance of GWs has previously been demonstrated for the general circulation of Earth's upper atmosphere using the whole atmosphere parameterization [Yigit et al., 2009; Yigit and Medvedev, 2009]. Despite numerous observations however, the global picture of GW activity is yet to be revealed both on Earth and Mars.

In order to investigate the global distribution of small-scale GWs in the Martian atmosphere, we have conducted the first simulations with a high-resolution MGCM, using the DRAMATIC (Dynamics, RAdiation, MAterial Transport and their mutual InteraCtions) MGCM [e.g., Kuroda et al., 2005, 2013]. The MGCM was run at the T106 spectral truncation, which corresponds approximately to a 1.1^{o} x 1.1^{o} (or ~60 km) horizontal resolution. In the vertical direction, the model domain extends from the surface to ~80–100 km and is represented by 49 sigma-levels. Such setup allows for realistically capturing generation and propagation of GWs with horizontal wavelengths of ~180 km and longer and, to some extent, their vertical attenuation due to nonlinear processes. We considered horizontal-scale fluctuations with a total wave number of larger than 60 (horizontal wavelengths of less than ~350 km) as GW-induced disturbances.

We investigated the spatial distributions of potential and kinetic energies associated with GW activity in the northern winter solstice. The simulated GW potential energy distribution is in a good agreement with available radio occultation data [Creasey et al., 2006] in the lower atmosphere between 10 and 30 km. The model reveals a latitudinal asymmetry with stronger wave generation in the winter hemisphere, and investigations from the ratio of potential and kinetic energies show that there are two distinctive sources of GWs: mountainous regions and the meandering winter polar jet. Orographic GWs are filtered upon propagating upward, and the mesosphere is primarily dominated by waves with faster horizontal phase velocities. Wave fluxes are directed mainly against the local wind, with a clear relation between wave dissipation and wind acceleration. GW dissipation in the upper mesosphere generates a body force per unit mass of tens of m s^{-1} per Martian solar day (sol^{-1}), which tends to close the simulated jets. Effects of horizontal propagation of GWs on the acceleration are much smaller than those of vertical propagation, and the results of acceleration rates are comparable to those obtained from the application of the GW parameterization by Yigit et al. [2008], which considers only the vertical propagations of a broad spectrum of GWs.

The results represent a realistic surrogate for missing observations, which can be used to further constrain existing GW parameterizations and validate GCMs. Also the observational investigations of GW signatures in the thermosphere by the MAVEN mission would help better understand propagation and

dissipation mechanisms of GWs.

Keywords: Mars, Atmospheric dynamics, Gravity waves, General circulation model, MAVEN

Fluorescence Life-Time (FLiT) instrument for space missions

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While we detail the design of the Life-Detection Microscope (LDM), a high spatial resolution fluorescence microscope, alternative ways of detecting extraterrestrial life have been under consideration. One of such is the "fluorescence lief-time (FLT)" measurement. FLT has been widely used in biophysical studies of proteins as FLT by its nature is one of the most robust fluorescence parameters. To examine the possibility of applying the FLT measurement to the space missions, we have developed a Bread Board Model (BBM), called FLiT. The method we use is the "time-domain" method in which the sample is illuminated with a short pulse laser and the decay time of the fluorescence is measured.
The pulse laser of FLiT is a 488-nm laser diode (Nichia NDS4116) to which pulses of 1-ns full width at half maximum is fed by the driver electronics. One pulse may excite just one fluorophore and the photon from it will be detected by an avalanche photo diode (APD) in the photon-counting mode (MPPC C13001-01 from Hamamatsu Photonics). The time delay from the start trigger (1-ns pulse) to the stop trigger (photon detection in MPPC) is measured by the time-to-digital converter (TDC7200 from TI). Such measurement will be repeated and a histogram of delays is obtained from which the fluorescence life-time of the sample material is inferred. This potentially allows us to distinguish organisms from minerals in the Martian soil. The FLiT BBM is now under the characterization phase, to evaluate possible delays in the electronics (including cables) and their stability. Details of the FLiT BBM as well as results of initial tests will be presented.

Keywords: Fluorescence life-time, Martian life, Life-detection microscope

