Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-01 Room:103 Time:May 25 08:30-08:45

Mars Exploration Mission MELOS: An Overview

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While the scientists group continues discussion on the scientific target for Japan's Mars mission, a "sure" step of exploration needs to be followed from the engineering point of view. The idea is that we will achieve an orbital insertion plus entry-descent-landing (EDL) demonstration in MELOS1 mission. The EDL module will also carry a fair amount of science payload so it is not a mere demonstrator but also a platform of scientific mission. A upscale MELOS2 mission with a well-equipped lander will follow and enhance, together with MELOS1 and future MELOSX missions, our understanding about the red planet, Mars.

Currently, there are 2 proposals for the orbiter mission. One is Martian meteorology that complements the comparative study of terrestrial planet's meteorology. Unfortunately, Akatsuki's first attempt of Venus orbital insertion (December 2010) turned out to be unsuccess, there is a good chance of another orbital insertion a few years later. The knowledge of the Earth meteorology will be improved by Akatsuki at Venus and by MELOS1 at Mars. Another is the escaping atmosphere that is thought to be a key process of today's tenuous atmosphere of Mars. To overcome NASA's MAVEN (launch in 2013), a group of people proposes a "2 orbiter" configuration for this mission. The mission needs to be around the maximum of 25th solar cycle (˜2024). The lander group proposes 4 themes: the surface environment study with a rover; the interior study through seismology and rotation measurements that benefit most from a network of ground stations; astrobiological study that focuses Martian methane and related possible metabolism; and a "flyby" sample return mission that captures the dust and the atmosphere ˜40-45 km altitude while flying.

Proposed ideas are all unique and valuable for the study of Martian system that produced today's dry/cold environment of Mars. We continue evaluation of proposals in 2011 and 2012. Will decide what we will do with MELOS1 (an orbiter and an EDL demo) by fall of 2012. The mission will then be proposed for launch in early 2020's that will be a similar time frame with NASA's MSR (Mars Sample Return) Orbiter and ESA's network lander mission.

Keywords: Mars exploration, system science, orbiter, lander, evolution history, habitability

Japan Geoscience Union Meeting 2011
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PPS002-02 Room:103 Time:May 25 08:45-09:00

Regional characteristics of dust haze transport on Mars

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Regions favorable (FRs) for expansion of dust storms on Mars are identified. We performed many numerical simulations where, in the northern fall (Ls=180), dust was injected into the atmosphere artificially from dust sources located all over the planet. Such dust transport simulations provide global maps of dust expansibility (i.e. ”dust expansion potential”) and show that dust expansibility differs greatly between different regions on Mars. These global maps show that dust loaded from certain areas in the northern mid-latitudes tends to spread widely within a few days. Dust injected in the vast regions around Tharsis and the Sirenum-Aonia regions also tends to spread extensively depending on local time. On the other hand, dust injected at high latitudes in either hemisphere does not spread extensively. Such global maps indicating regions favorable for dust storm expansion are a clue to understanding expansion processes and climatology of great dust storms on Mars. Moreover, none of the approach described in the presentation to understanding expansion processes and climatology of great dust storms has been taken elsewhere. In out presentation, we present results of simulations for other seasons as well as Ls=180 and consider concrete mechanisms of dust expansion in and around each FR.

Keywords: Mars, dust storm, transport, numerical simulation

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-03 Room:103 Time:May 25 09:00-09:15

General circulation and dynamics of Martian middle atmosphere

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For the Martian atmosphere, there are much less observational data of middle atmosphere (60-130 km altitude) in comparison with the lower (0-60 km altitude) and upper (higher than ˜130 km altitude) atmosphere. But recent studies using the limited observational data and numerical simulations show the importance of middle atmosphere sciences for the climate change and atmospheric escape of Mars.

Atmospheric dust and water on Mars are transported by the meridional circulation. Studies using Mars General Circulation Models (MGCMs) show the seasonal changes of the meridional circulation due to the distance from the Sun and the effects of topography. Especially in southern summer when it is close to the perihelion, the atmospheric temperature becomes globally higher than in northern summer, which is thought to allow the water vapor to go higher and enhance the meridional transport of water from south to north. Moreover, planet-encircling dust storms sometimes occur in southern summer, which is thought to strongly enhance the meridional circulation due to the strong radiative heating by dust in southern hemisphere. But we have never done the mapping of the temperature and wind fields of the middle atmosphere to prove these hypotheses.

The stellar occultations by SPICAM onboard Mars Express have detected several vertical profiles of temperature in the middle atmosphere. In most of the observed profiles the temperature around the height of ˜100 km goes below the CO_2 condensation level, which indicates the existence of CO_2 ice clouds in the height of 60-100 km. Actually cameras onboard Mars Express and Mars Odyssey have observed the CO_2 ice clouds, and the clouds have also been used to detect the wind velocity of middle atmosphere by the cloud tracking method. Note that the wind velocity of middle atmosphere has also been detected from the Doppler shifts on the molecular lines observed from ground-based sub-millimeter telescopes. But the observed temperature and wind fields of Martian middle atmosphere are not well reproduced by current MGCMs, which, for example, the simulated temperature of mesopause (80-100 km altitude) overestimates in 10-30 K and the simulated easterly wind velocity in low latitude of northern summer is less than half of the observations. These discrepancies are probably because of the lack of the effects of gravity waves from lower atmosphere, underestimations of the atomic oxygen concentration which controls the CO_2 infrared cooling, and so on. Moreover, there are studies which indicate the effects of dynamics and material transport in lower atmosphere on the structures of ionosphere. Investigations of the middle atmosphere are important to understand the atmospheric science connected from the surface to ionosphere.

We are proposing the observational plans of Martian middle atmosphere with the MELOS Meteorological Orbiter, which include the mapping of temperature fields, wind fields and compositions from a sub-millimeter sounder and the tracking of CO_2 ice clouds from cameras. In this presentation we introduce the preceding studies of Martian middle atmosphere, and discuss the significances of the mission plans.

Keywords: Mars, Planetary atmosphere, Atmospheric dynamics, Sub-millimeter observation, Space exploration, MELOS

Japan Geoscience Union Meeting 2011
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PPS002-04 Room:103 Time:May 25 09:15-09:30

Atmospheric convection with condensation of the major component

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In Martian atmosphere, atmospheric major component, CO2, condenses.
In current Martian polar regions, CO2 ice clouds are known to exist, and there is a possibility that these clouds are formed by convective motion (Colaprete et al., 2003).
Studies on the early Mars suggested that large amounts of CO2 ice cloud existed in the thick atmosphere, and that the scattering greenhouse effect of CO2 ice cloud had a significant effect on the climate (Forget and Pierrehumbert, 1997: Mitsuda, 2007).

In a system whose major component condenses, the degrees of freedom for thermodynamic variables degenerate when supersaturation does not occur.
Due to degeneracy of degree of freedom, temperature profile of ascent region must be equal to that of descent region, and air parcel can not obtain buoyancy.
Colaprete et al. (2003) performed calculations by using a vertical one-dimensional model and showed that moist convection develops when critical saturation ratio (Scr) is greater than 1.0, because the supersaturation will permit the temperature profile to deviate from the thermodynamic equilibrium.
However, in the vertical one-dimensional model, there is an uncertainty in the parameterizations related to the effects of entrainment and so on.

In this study, we perform a direct numerical calculation of cloud convection using cloud convective model developed by ourselves (e.g., Odaka et al., 2006: Sugiyama et al., 2009: http://www.gfd-dennou.org/library/deepconv/index.htm.en) in order to investigate the properties of flow field and cloud distribution in the case of Scr = 1.0.
The used model is a two-dimensional cloud convection model that incorporates condensation of the major component, CO2.

The governing equations in our model are the quasi-compressible equations by Klemp and Wilhelmson (1978) with additional terms representing the major component condensation (Odaka et al., 2005).
Gravitational settling of cloud particle and drag force due to cloud particles are not considered.
We assume that cloud particles grow by diffusion process.
We formulate the cloud microphysics by using the equation of diffusion growth of cloud particles as Tobie et al. (2003).
In this formulation, conversions from the vapor to the cloud occur within finite time scale.
We do not calculate radiation transfer explicitly, but we give horizontally uniform body heating near the surface and horizontally uniform body

cooling in the troposphere.
As initial temperature profile, we give the profile in which temperature follows the dry adiabatic lapse rate in the lower layer, and follows the saturated vapor pressure in the upper layer.
As initial perturbation, random noise is added to the lowest layer of atmosphere.
Integration time is 10 days.

Our result shows that moist convection develop in the case of Scr = 1.0. This result is different from that of Colaprete et al. (2003). In the quasi-equilibrium state, The updrafts that occur above and below the CO2 condensation level are connected at the condensation level. The downdrafts are also connected at the level. Maximum vertical velocity in both dry and cloud layer are about 15 m/s. Ascending air parcels experience positive and negative buoyancy below and above the CO2 condensation level, because they are warm compared to surrounding air under the level and they are cold above the level.
On the contrary, descending air parcels are warm in cloud layer, and cold in dry layer.
Since time scale of conversions from vapor to cloud is finite, temperature deviates from the saturated one in the cloud.
The reason why moist convection develops is that positive buoyancy in dry layer is sufficiently large compared to negative buoyancy in cloud layer when air parcels go up.

Keywords: condensation of major atmospheric component, carbon dioxide ice cloud, cloud convection model

Japan Geoscience Union Meeting 2011
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PPS002-05 Room:103 Time:May 25 09:30-09:45

Methane on Mars: Current observations and implication

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Since the simplest organic molecule, methane (CH4), was detected in the Martian atmosphere in 2004, this topic has caused a big interest in the solar system, because its discovery indicates the planet is either biologically or geologically active. Up to now, ground-based and space-born observations have confirmed its presence in the Martian atmosphere (Formisano et al., 2004; Krasnopolsky et al., 2004; Geminale et al., 2008; Mumma et al., 2009; Fonti and Marzo, 2010). However, its reservoirs, release mechanisms, circulation, and sink are still open questions. The high-spectral resolution observation from ground-based telescope indicated that CH4 showed time variation, and non-uniform distribution, with plume-like features at discrete regions (Mumma et al., 2009). Using the Planetary Fourier Spectrometer (PFS) onboard Mars Express (MEX), Geminale et al. (2011) also reported maps of non-uniformed CH4 distribution. Although the MEX/PFS and the ground-based observations were generally not collected at the same time nor did they cover identical areas of Mars, the characteristics of the observed CH4 fields appear to be significantly different. In contrast, photochemistry as currently understood does not produce measurable variations in CH4 concentrations [Lefevre et al., 2009]. Lefevre et al. (2009) suggested an atmospheric lifetime of less than 200 days is necessary to reproduce the local CH4 enhancements similar to those recently reported, which implies an unidentified CH4 loss process that is 600 times faster than predicted by standard photochemistry. In summary, current photochemical models cannot explain the observed presence of CH4 in the atmosphere of Mars and its reported rapid variations in space and time. The origin and sink of CH4 on Mars remains a puzzle. In the near future, the observations using heterodyne spectroscopy with an alternative CH4 band near 7.8 um [Sonnabend et al., 2008] are begun to monitor CH4 from the ground, and the tunable laser spectrometer measurements is carried out at the Martian surface on the 2011 Mars Science Laboratory (MSL) to identify the isotope of CH4 [Webstar et al., 2011]. Joint orbiter mission being considered by ESA and NASA (JIDT) is also expected to provide the significant scientific progress on this issue by investigating the nature of the trace gas with measurements of temperature and aerosols (Zurek et al., 2011). Here we review the current observations of Martian CH4 and their implications.

Keywords: Mars, Methane, Life, Habitability

Japan Geoscience Union Meeting 2011
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PPS002-06 Room:103 Time:May 25 09:45-10:00

Search of H_2O_2 in the Martian atmosphere by MEX/PFS

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Recently, a small amount of CH_4 was discovered in the Martian atmosphere. This discovery is remarkable because its sources are potentially biological or geological actives. However, its source, circulation and sink are still open questions. Recent observations showed the temporal and spatial variation of CH_4, which requires fast loss, which might indicate strong oxidants. H_2O_2 would be the best tracer for the amount of possible oxidants in the Martian atmosphere. However, past ground-based and space-born observations were very limited. Thus, the temporal and spatial variations of H_2O_2 have not been understood yet.

H_2O_2 has not detected from a Martian orbiter because it required high-spectral resolution in order to distinguish between weak absorption lines of H_2O_2 (~0.1% of the background radiance) and stronger absorptions by H_2O. At the moment, the Planetary Fourier Spectrometer (PFS) onboard Mars Express (MEX) is the best instrument for this objective, which has been successfully operated for seven years. It possesses the highest spectral resolution in the mid-IR range (~1.3 cm^{-1}) in previous orbiters. However, even this resolution could not completely separate H_2O_2 from H_2O. We need careful treatment in the analysis.

In our study, we select the wavelength range from 360 to 385 cm^{-1} where the contamination of H_2O_2 by H_2O is minimum. And, the sensitive calibration was performed: (1) FFT with the Hamming apodization, (2) characterization of a weak instrumental noise, and (3) careful averaging several thousands of measurements. In order to retrieve the mixing ratio of H_2O_2, the radiative transfer model for the Martian atmosphere has also been developed. By the comparison of the observed spectra with the model, we succeeded to determine the mixing ratio of Martian H_2O_2 with the accuracy of several tens ppb. By this method, (1) total average, (2) annual variation, and (3) seasonal variation of the H_2O_2 mixing ratio was obtained with the data observed 3 Martian years (Jan. 2004 - Dec. 2009). The main results are summarized as follows.

(1) Total average: Total averaged H_2O_2 mixing ratios have been successfully determined to be 45 +- 21 ppb in the forward pendulum direction, and 25 +- 18 ppb in the reverse pendulum direction, respectively.

(2) Annual variation: The annual mean amount of H_2O_2 in the three Martian years (MY 27, 28, and 29) was investigated. The mixing ratios of H_2O_2 were 50 +- 27 ppb and 43 +- 26 ppb at the MY 27, 0 - 89 ppb and 0 - 74 ppb at the MY 28 (upper limits), and 46 +- 21 ppb and 28 +- 20 ppb at the MY 29, respectively

(3) Seasonal variation: It shows the variation from 0 to 120 ppb during the observational period, with an average of 39 +- 16 ppb in total data set.

In all results of (1)-(3), derived amount of H_2O_2 is slightly larger than that predicted by the photochemical models and past observations. This discrepancy would be due to (1) the bias of data selection; the high Martian temperature (only 250-270K)> and the local time (only 10-16), and/or (2) the contribution of large but short enhancement in long-term average. In addition, it was noticed that the observational variations of CH_4 reported by previous works would not be explained by the process of photochemical loss even with our results.

Keywords: Mars, Atmosphere, Infrared spectroscopy, Methane, Oxidation, Hydrogen peroxide

Japan Geoscience Union Meeting 2011
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PPS002-07 Room:103 Time:May 25 10:00-10:15

Development of Martian meteorological Instruments

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We are developing weather observation instruments install on the lander of Mars of MELOS.
At now, there are some observation on Mars, but all observation are made with basic instruments.
Then, we are examining two kinds of instruments at the same time.
One of that is a set of basic instruments, the thermometer made of thermocouple or so, the manometer, these are always used for radiosonde.And a hot-film (similar to hot-wire) anemometer, this type is boarded on Viking.
The other instruments are mainly sonic anemometer, it improve high accuracy and high frequency in low electrical power.
Mars has a very low pressure of CO_2 atmosphere, sonic wave damping is very strong, so development has a difficulty.
However some reports say it will be possible, and we are examining a possibility, we report mainly around the progress of this possibility test.

Keywords: Mars, Meteorology, anemometer, Lander, MELOS

Japan Geoscience Union Meeting 2011
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PPS002-08 Room:103 Time:May 25 10:15-10:30

FIRE: Submillimeter sounder for the Maratian atmospheric observations

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This paper describes the development status of a submillimeter atmospheric emission sounder FIRE which is proposed as an onboard payload of the Japanese Mars meteorological orbiter MELOS.

The submillimeter wavelength has potential advantages for the atmospheric remote sensing as there exist a large number of roto-vibrational transitions of many photochemically important species in the Martian atmosphere such as H2O, H2O2, HO2, CO, O2, O3 and SO2. The vertical profiles of the atmospheric state (e.g., temperature, chemical compositions) can be retrieved by using the pressure dependency of the spectral line shape of those rotational transitions. Furthermore, thanks to high frequency resolution of the heterodyne technique, direct measurements of wind speed are realized through observing the Doppler shift of the molecular spectrum. Last but not least, the submillimeter observation is independent of dust opacity and local time. All these characteristics make the submillimeter instrument unique, and will provide a substantial progress on the Martian meteorological understanding.

We present the results of the measurement sensitivity study with respect to the key physical parameters such as H2O, temperature, HDO/H2O, and line-of-sight wind velocity, with assuming realistic instrumental parameters.

Keywords: Mars, sub-mm sounder

Japan Geoscience Union Meeting 2011
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PPS002-09 Room:103 Time:May 25 10:45-11:30

Exploring the Martian Surface: Lessons Learned from Thirteen Rover-Years on Mars

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The two Mars Exploration Rovers, Spirit and Opportunity, touched down on Mars in January 2004 and have been conducting extensive observations with the Athena science payload. Together the two rovers have traversed about 35 km. Spirit, located on the floor of Gusev crater, has investigated basaltic plains, as well as older materials in the Columbia Hills. The rocks of the Columbia Hills are granular in nature and have undergone significant alteration by water. They appear to be largely a mixture of altered impact ejecta and explosive volcanic materials. Spirit has discovered silica-rich deposits that may have formed in a hot spring or volcanic fumarole environment, as well as massive carbonate-rich rocks. Opportunity has carried out the first outcrop-scale investigation of ancient sedimentary rocks on Mars. The rocks are sandstones formed by wind and water erosion and re-deposition of ”dirty evaporite” materials rich in sulfate salts. The stratigraphic section observed to date is dominated by wind-blown bedforms, with water-formed current ripples exposed locally near the top of the section. While liquid water was present at Meridiani below and occasionally at the surface, the ancient environmental conditions recorded there are dominantly arid, acidic and oxidizing, and would have posed some significant challenges to life.

In carrying out the rovers’ mission, many lessons have been learned regarding the operation of robotic vehicles on the surface of Mars. These cover topics including flight system and mission design, traverse planning, science payload selection, flight software and autonomy, and team selection and training. Among the most important flight system capabilities are mobility, particularly in steep and rugged terrain, and a power system design that allows long mission life. Traverse planning benefits greatly from high resolution orbital imaging, and should take full advantage of topographic features, like impact craters, that provide access to important geologic materials. Important payload elements include instruments that can detect subtle compositional differences both remotely and in situ, and tools for getting below rock and soil surfaces. The most important flight software capabilities are ones that save time on the martian surface. Similarly, it is important to invest in the tools and team training necessary to minimize the duration of the uplink planning process.

Keywords: Mars Exploration Rover, Spirit, Opportunity, Operation, Science, Engineering

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-10 Room:103 Time:May 25 11:30-11:45

Possibly water-related active features on Mars: Their climatic and biological implications

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Currently active features on Mars include numerous flow-like features identified mostly in higher latitude areas. Although liquid water has long been considered impossible to stably exist under the current climate condition, origins of some flow-like features are proposed to be related to liquid water based on their morphologies and remaining chemical compositions. Because the presence of water ice in shallow subsurface and water vapor are known to exist on Mars, water-related active processes might be a part of the story of long-lasting slow circulations of water on the surface of Mars, which might be an intriguing target for synergetic observations between the orbiter and the rander of the future MELOS mission to Mars.

The rander group of the MELOS mission is actively discussing its mission concepts, which include a biological aspect. One of the biggest goals proposed is to critically discuss if certain types of bacteria are still alive on Mars. A tentative scenario drawn for this purpose is to explore source areas of putative discharge of Methane, which may include mud volcano-like features widely spread western side of Elysium. In this talk, I will review current understanding of the flow-like features as well as other features indicative of the previous presence of liquid at a little deeper depth, such as mud volcanoes, and discuss their implications to the mission concept of the MELOS mission.

Keywords: Mars exploration, MELOS, Mars, water, periglacial area

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-11 Room:103 Time:May 25 11:45-12:00

Sulphate-rich bedrocks at Meridiani Planum, Mars: Constraints and modelling

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The sulphur-rich nature of Martian soils is known since the Viking missions [1]. Data from recent orbital and landed missions have confirmed the important role played by the sulphur cycle on Mars [2] by showing that sulphates were among the most abundant secondary minerals on the Martian surface. Understanding which geological processes led to their formation is of particular interest as it may yield important clues about the presence of water during Mars' geological history. In this context, data from the Mars Exploration Rover (MER) Opportunity provide crucial constraints on the conditions prevailing during the formation of Meridiani Planum sulphate-rich bedrocks. Terrains visited by Opportunity at Meridiani appear to be sulphur-rich (up to 25 % SO3) layered rocks covered by basaltic soils [3]. Outcrops are exposed by impact craters, allowing their analysis by the rover's instruments. Another notable feature of these plains is the ubiquitous presence of mm-sized spherules, containing hematite, observed in both the rocks and the soils. Some mafic constituents are also present in the rocks.

In addition to hypotheses formulated before the beginning of on-site observations, such as subaqueous sedimentary deposition [4], various formation scenarios have been proposed (or significantly refined) since the landing of the rover: impact surge [5], weathering of dust-ice deposits [6], alluvial deposition of exogenous materials [7], groundwater diagenesis of evaporitic sandstones [3,8], volcanic processes [9], and alteration of basaltic material through sulphur-bearing fluids [10,11]. It is worth to note that these models are not necessarily all mutually exclusive. Numerous constraints exist as regards these hypotheses, relative to the chemical/mineralogical compositions (including variations within the investigated layers), the provenance of the constituents involved in the formation scenario (including water, if needed), the textural observations, etc. The large-scale geological context, known from orbital data, has also to be taken into consideration [12], especially as the rock layers investigated by Opportunity only represent a small part of the full stratigraphic sequence of sulphate-bearing layers at Meridiani.

All the proposed scenarios have their own advantages and issues. The model of alteration of basaltic material through cold sulphur-bearing fluids [10,11], using a geochemical numerical simulator, provides particularly interesting results. Here, acidic fluids are assumed to originate from volcanic sour gas dissolution into pure water and the main parameter of the model is the quantity of added sulphur, expressed in terms of SO3/basalt mass ratio. The role of brine circulation is also taken into account. A good match with MER observations at Meridiani is obtained for a particular adjustment of the model parameters suggesting an alteration occurring in highly acidic brines and involving small amounts of water over a short period of time (or in an intermittent way). Additionally, the potential mineralogies obtained through this model over a wider range of initial conditions could also explain compositions encountered in other Martian regions.

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Keywords: Mars, Meridiani, alteration, sulfuric acid, Mars Exploration Rover, geochemical modelling

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-12 Room:103 Time:May 25 12:00-12:15

Diversity of Martian meteorites and its relationship to the remote sensing data as obtained by Mars exploration

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Recent recoveries of many hot and cold desert meteorites have drastically increased the number of Martian meteorites. We only had 10 samples in early 1990s, but now we have more than 50 unpaired samples. At the same time, the accumulation of remote sensing data by Mars mission has been considerably increasing for the past 15 years. Therefore, now is a good time to compare Martian meteorites and remote sensing data to construct the better view of the red planet.

In spite of the increase of recovered Martian meteorites, classic grouping as ”SNC” (shergottite-nakhlite-chassignite) meteorites is still alive probably because many samples were transported to the earth by the same ejec-tion event. Except for ALH84001, all other samples can be grouped as either of ”SNC” with young crystallization ages (170-1300 Ma). Therefore, these samples probably originated from Tharsis or Elysium regions. It is still unex-plained why ALH84001 is the only old sample possibly originating from the southern hemisphere. All Martian meteorites are igneous rocks, and no sedimentary rocks have been found yet, although both orbiters and rovers have found the wide distribution of sedimentary rocks. One of the explanations is that these altered rocks can not be ejected into the space because of fragile nature of the rock.

Shergottite is still the largest group of Martian meteorites that are generally divided into three subgroups (basaltic, lherzolitic, and olivine-phyric) based on petrology and mineralogy. In recent years, geochemical studies have shown that shergottites can be divided into another three subgroups (enriched, depleted, and intermediate) based on distinct trace element and isotopic compositions, which is completely independent from petrological subgrouping. Their redox states are closely related to these geochemical characteristics, and interpreted to reflect the heterogeneity of the mantle reservoirs [e.g., 1]. These reservoirs formed about 4.5 Ga in a global magma ocean and kept separated because of the absence of active plate tectonics since the reservoirs formed. The second largest group is nakhlite that now consists of 8 samples. Because all nakhlites show similar mineralogy and ages, they probably originated from the same igneous body on Mars with possible layering by accumulation of crystallizing minerals. Each nakhlite is modeled to fit the location from near the surface to the depth of this igneous body. Nakhlites show minor evidence for secondary aqueous alteration that is related to the burial depth as inferred from igneous accumulation. There are a few alteration phases, but the presence of jarosite is important because it is one of the major alteration products on the surface as discovered by Mars Exploration Rover. Two chassignites are dunite rocks that have identical ages to nakhlites. The second chassignite shows black appearance because of the presence of Fe-rich nano-particles in olivine formed by shock metamorphism. ALH84001 is the only old Martian meteorite and the presence of possible biogenic magnetite is still under dispute.

Thus, Martian meteorites are important sources to deduce differentiation history of the planet. However, caution should be taken when we discuss a global view of the planet because of their young formation ages [2]. In fact, the chemical composition of the surface obtained by orbiters showed that the majority is tholeiitic basalts and Martian meteorites have distinct chemical compositions. Obviously Martian meteorites do not represent old crustal chemistry although they record that the planet’s interior preserves distinctive regions that formed at 4.5 Ga.

References: [1] Borg L. E. et al. (2003) GCA 67, 3519-3536. [2] McSween H. Y. Jr. (2009) Science 324, 736-739.

Keywords: martian meteorites, mars exploration

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-13 Room:103 Time:May 25 12:15-12:30

Mars Landing System for Surface Science in MELOS Mission

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Mars landing exploration system is being studied in MELOS, a Japanese Mars mission under study, including deployment from orbiter, entry into martian atmosphere, descending with aerodynamical control by heat shield, followed by parashute decelaration, landing with hazard aboidance, navigation and control, deployment of rover, and long-term operation on the Mars. Landing system and the following scientific observation as a long-lived station. Such landing and surface exloration system is briefly reported in this presentation.

Mars is among the extremely attractive planets to be explored in its nature: inner structure, surface processes, weather and climate system, and atmospheric escape. Furthermore, there are planned a sample return of dusts floating in the air and an exploration of life in the habitable zone showing aquifer or methane gas. In the MELOS mission, all of these aspects are studied and some of them will be selected as a united Mars mission to be proposed as a MELOS series.

Entry, descent and landing (EDL) as well as surface long-lived technology and surface rover technology are yet to be developed in Japan but essential for the missions of inner structure, surface processes, and life on Mars. Thus the EDL of a probe from Mars orbiter and the surface long-lived technology on the Mars are investigated in this study to clarify the techinical problems and estimate the feasibility.

Three kinds of entry probes are assumed: A) a 700kg class probe to land a 500kg class lander with a 100kg class rover with 20 to 25 kg science payloads carried. B) two 350kg class probes to land 300kg class lander with 20 to 25 kg science payloads. C) 450kg and 250kg probes to land a 400kg and a 200kg landers, with 30kg class rover on the large one, and with 20 to 25 kg science payloads.

To start this study, we assumed that the launcher is H-2A-204, with 1.8t wet mass of the orbiter and landing system. The orbit of the orbiter is 300km x 10 Mars radius. The probe should survive during cruise using a internal heater.

The lander is a legged lander with aerodynamically decrease by heat shield and parashute, and controls its attitude for soft and smart landing by RCS (Reaction Control system) and reaction wheel (RW). The lander is expected to survive in the winter season for a long-lived station to investigate inner structure.

The lander instruments include seismometry, mass spectrometer, X-ray analyzer, landscape and macro imagers, magnetometer, space VLBI, meteorological package, atmospheric radio sounding in 25 kg. Rover is mounted on the lander. Communication system has X-band for direct link to the terrestrial station and UHF band for link to the orbiter. Battery and solar paddle for energy and thermal control are prepared for survivability even in the winter.

The feasibility of such EDL and long-lived technology has been examined to find a solution for a mission success as well as low cost in the spacecraft system.

Keywords: Mars, Landing, Geological Survey, Inner structure, Atmosphere Observation, Rover

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-14 Room:103 Time:May 25 12:30-12:45

MELOS Life Search plan: Search for microbes on the surface of Mars

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The liquid water is considered to be an critical factor for life. Gibbs free energy is another factor that should be counted to sustain life for long duration. The Gibbs free energy is obtained by reaction between reductant and oxdidant, or from any other non-equilibrium state of matter. As an example, aerobic organisms use carbohydrate and oxygen for getting Gibbs free energy. Many types of chemoautotrophic mechanisms are known for the process as well. On Mars surface, methane and oxidative compound such as ferric oxide or sulfate are found, and they can be a sourse of Gibbs free energy. Iron-dependent methan oxidizing bacteria was found in marine emviroment on Earth (1). This finding suggests possible presence of methane-oxidizing bateria on Mars surface, if local thermal environment and other resources permit proliferation and metabolism of the bacteria during limited portion of time period.

Our project aims to search for the methane-oxidizing microbes on Mars surface. Martian soil will be sampled from a depth of about 5 or 10 cm below the surface, where organisms are supposed to be protected from harsh hyper-oxidative environment of Mars surface. Small particles less than 0.1 mm are sieved from the sample, before transferred to analysis section by a micro-actuator. The particles are stained by cocktail of fluorescence reagents, and examined by a fluorescence microscope.

Combination of fluorescence dyes is selected to identify life forms from the soil sample. Intercalating fluorescence dye such as SyberGreen is used to detect genetic compounds such as DNA. Membrane specific dye or the combination of dyes is used to detect membrane surrounding the cell. Substrate dye that emits fluorescence upon cleavage by the catalytic reaction is used to detect the catalytic activity of the cell. A combination of staining reagents is chosen based on the definition of life. DNA or genetic material is required for replication of life form. Membrane separating cell from ambient leads to identification of individual. Catalytic reaction of enzymes drives metabolism. The combination is useful also for detecting pre-biotic organic material as well as remnant of ancient life.

Hydrolysis of the polymers in the cell followed by HPLC or soft ionization MS for amino acid analysis is effective in examining whether Martian life is identical or different from terrestrial life. The number and type of the amino acids as well as chirality will be analyzed to distinguish if the polymers are contamination made by Earth-related life form.

Reference: (1) E. J. Beal, et al (2009) Science 325, 184-187

Keywords: Surface of Mars, Life search, microbe, methane oxidizing bacteria, fluorescence microscope

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-15 Room:103 Time:May 25 14:15-14:30

What we have learned about the internal structure of Mars

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Mars has long been a target of exploration missions. Now we know the size and mass of Mars, that Mars has rarefied atmosphere and seasons, that Mars has obvious north-south dichotomy, and that Mars has the largest volcano in the solar system at the equator region. Then, what have we learned about internal structure of Mars?

The bulk density of Mars means that there is a dense core at the center of Mars. On the other hand Mars does not show intrinsic magnetic field, which means no vigorous convection in the core. According to the observation of gravity and topography the crustal structure of Mars shows contiguous thickening from north to south, which means long wave length mantle dynamics. The large volcanoes should have been supported by superplume.

In this talk, I will review what we have learned about the internal structure and thermal evolution model of Mars, and discuss what should be observed next to unveil the interior and history of Mars.

Keywords: Mars, internal structure, thermal evolution, mantle dynamics

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-16 Room:103 Time:May 25 14:30-14:45

Numerical models of Martian mantle evolution induced by magmatism and solid-state convection

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To consider the thermo-chemical evolution of Martian mantle, various studies have been performed, but most of them are based on parameterized convection models. Hence, they needed strong assumptions about the process of the evolution. Here we present numerical models of mantle evolution including magmatism in 2-D convecting mantle. By including magmatism, our models can reproduce compositionally layered mantle structure and surface crust spontaneously, and can treat the whole evolution process consistently. The viscosity is strongly temperature-dependent, and the lithosphere is stagnant. Magmatism is modeled as a permeable flow of basaltic magma generated by decompression melting. The effect of partitioning of heat producing elements into the melt is also included. When the initial mantle temperature is sufficiently high, a reminiscence of magma ocean develops to generate a thick basaltic crust and make the mantle compositionally layered. The upper layer consists of compositionally buoyant residue of the basaltic crust, while the lower layer consists of compositionally denser materials not depleted in the basaltic component. Hot plumes grow from the lower layer and make it thinner with time by erosion. The plume magmatism also keeps the mantle temperature below the solidus by efficiently extracting heat as soon as the mantle temperature exceeds the solidus. When the mantle is initially not so hot as to develop a sizable magma ocean, the compositional layering becomes milder, and a broad lateral heterogeneity temporally develops in deep mantle depending on the viscosity of the lithosphere. Martian mantle is likely to have evolved as a relaxation from a compositionally layered state formed by magma ocean, and plume magmatism probably has played a crucial role in the relaxation process.

Keywords: Mars, mantle evolution, magmatism, basaltic crust

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-17 Room:103 Time:May 25 14:45-15:00

Measurements of Martian rotational variations by space geodetic techniques

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Variation of planetary rotation provides us information concerning both the interior structure and the surface mass redistribution. Such information is valuable for elucidating not only present condition but also evolution of a planet as a system. Precession and nutation of Mars reflect the present status of the core-mantle sub-system, besides length-of-day variation and polar motion of Mars are induced by variation of the atmosphere-cryosphere sub-system.

Two-way tracking of orbiters on Mars were executed to elucidate the physics of Mars. Precession and length-of-day variation have been measured by means of tracking data of Viking 1 and 2, and Mars Pathfinder. The results of the Love number k{sub}2{/sub} obtained by two Martian explorers, namely, Mars Global Surveyor (MGS) and Mars Odyssey, predict existence of a liquid core inside Mars. Seasonal variations of the polar caps on Mars were estimated mainly based on the laser altimeter data on MGS in conjunction with gravity data. Although Mars rotation observations by two-way tracking have produced scientific results as shown above, these measurements had limitations in terms of accuracy within the framework of traditional technologies concerning space geodesy and astrometry. Thus, the new configurations of orbiter-to-lander tracking had been proposed for two Martian explorers. To achieve the accuracies in the order of 1 mas (mill-arc second) to detect Martian rotation variation, orbiter-to-lander tracking were proposed for NetLander and ExoMars. Unfortunately these ideas have still not been approved as real missions for Mars.

A Japanese research group has recently started to plan a new Martian explorer; MELOS (Mars Exploration with Lander-Orbiter Synergy). As one of the missions of MELOS, we are proposing areodetic observations using space geodetic techniques such as four-way Doppler measurements and inverse VLBI [1]. By measuring the Mars rotation with higher accuracy, we will be able to determine the state of the core (liquid or solid) more clearly, estimate its radius if it is liquid, and figure out the quantities of seasonal surface mass redistribution. Four-way Doppler measurements (FWD) are ranging rate measurements of target spacecraft via relay spacecraft. Utilizing the heritage of FWD by SELENE, we plan to track the multi-landers of MELOS relayed by the MELOS Orbiter. The expected accuracies for these observations are almost in the same order as that in the case of orbiter-to-lander tracking. We also introduce a new technology called inverse VLBI. One ground radio telescope, not a VLBI network, observes both the orbiter and the landers with same-beam or switching of the antenna. The signals from the landers are coherently locked with those of the orbiter, and phase differences between the two spacecraft are also measured at the orbiter. The functions of the orbiter and the landers may be exchanged depending on the limits of resources including mass and electric power of each spacecraft, although, the precisions of the measurements are independent of such configuration changes. One of the remarkable characteristics of inverse VLBI is that the theoretical accuracy of positioning depends only on the observation frequency and does not depend on the distance between the radio sources and the ground stations. Therefore, X-band observation of inverse VLBI will achieve the accuracy of 0.3 mm which is much better than that of FWD, RARR, and differential VLBI. Including the systematic phase noise, the accuracy for the rotation is estimated to be better than 3 mas. The inverse VLBI system, however, needs higher carrier to noise ratio than conventional tracking, and therefore it is necessary to develop more efficient antenna and receiver system. It is also important to calibrate the phases through links with higher accuracies.

Reference: [1] Kawano et al. (1999) J. Geod. Soc. Japan, 45, 181-203.

Keywords: Mars, rotation, space geodesy, inverse VLBI

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-18 Room:103 Time:May 25 15:00-15:15

Global seismic waveform modeling in the whole Mars - a preliminary study -

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We calculate global seismic wave propagation on cross sections of realistic whole Mars models.

Estimation of Martian inner structure has been one of the most attractive topics in planetary science for decades. Indirect estimation of Martian interior has been attempted via various pieces of information such as cosmochemical data from the Martian meteorites, and planetophysical data such as the moment of inertia. Especially, Sohl & Spohn (1997, JGR) had proposed two end-member standard Mars models of density and seismic wavespeeds named “model A” and “model B” constructed in order to satisfy certain values of the polar moment of inertia and the bulk chondritic Fe/Si ratio, respectively.

Seismological estimation of the Martian inner structure is the next step although up to now only a possible small seismic event was detected during five months of operation of Viking 2 seismometer emplaced on Mars in 1976 (Anderson et al., 1977, JGR). Currently, preparation for the Japanese next Mars exploration mission MELOS is progressing, which contains a plan to install broad-band seismometers on Martian surface (e.g., Kurita et al., 2009, JPGU Meeting). Looking back on investigation history of the Earth’s interior, our knowledge has been enhanced by mutual progress of observation and numerical methods. Increased enthusiasm for Mars exploration in recent years strongly requires developing a method for numerical modeling of global seismic wave propagation based on our current knowledge of Martian interior.

We have been constructing numerical schemes using the finite-difference method (FDM) for accurate and efficient modeling of global seismic wave propagation through realistic Earth models with lateral heterogeneity (e.g., Toyokuni et al., 2005, GRL; Toyokuni & Takenaka, 2006, EPS). Our scheme calculates the 3-D equations of seismic waves in spherical coordinates only on a 2-D cross section of the whole Earth including a seismic source and receivers (spherical 2.5-D FDM), which enables global waveform modeling with the similar computation time and memory as for 2-D modeling with consideration of full 3-D geometrical spreading. This time we apply it to model global seismic wave propagation in the whole Mars. In the presentation, we will show some numerical examples using models with realistic Martian crustal thickness superimposed on the “model A” and “model B” of Sohl & Spohn (1997, JGR).

Keywords: Mars, seismology, seismic wave propagation, synthetic seismogram, global modeling, finite-difference method (FDM)

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-19 Room:103 Time:May 25 15:15-15:30

Consideration of broadband seismic observation on Mars.

yasuhiro nishikawa[1*], Akito Araya[1], Kei Kurita[1], Teruhito Hori[1], Naoki Kobayashi[2], Hiroaki Shiraishi[2], Nonaka Satoshi[2], Fukuda Wataru[2], Hideaki Kakuma[3], Yasushi Ishihara[4]

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The surface of Mars has been extensively investigated and huge amount of data have been acquired such as high Res images. On the other hand interior of the Mars has been only weakly constrained by the mean density, the moment of inertia and gravity data. The size of core is poorly constrained and negatively correlated with the core density. High dissipation state is reported for the mantle by tidal interaction (Bills et al 2006), which is against a conventional view of small,cool planet. To clarify these points seismic observation on Mars is deadly needed.

Japan Mars exploration project(MELOS) is now under discussion and it includes seismic measurements for determination the interior structure of Mars such as the core size, its state and attenuation in the mantle. Our plan is to install broadband high sensitivity seismometers,which are intended to detect continuous excitation of free oscillation by atmospheric turbulence. In this presentation we would like to show a basic design of broadband high sensitivity seismometer as well as environment protection designs. The basic parts are composed of a long period pendulum, laser interferometry and its control feedback electricity. As for the environment protection design,the following factors are important. Surface wind seems to be the most important and specific problem. We tested efficient design of wind shelter over the seismometer by wind tunnel experiment (low air pressure & high wind speed). We compared the experiments with computational fluid dynamics.

Keywords: Marsquake, free oscillations, inner structure, core size

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-20 Room:103 Time:May 25 15:30-15:45

Atmospheric electricity on Mars surface

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No measurement of atmospheric electric field and electromagnetic waves on the ground in Mars has been made, though it could dedicated not only to understanding of the electric current research but also to the meteorology. DC electric filed near surface is considered to play an important role in initiating dust devil. The electromagnetic wave measurement makes it possible to know the location and the quantitative strength of dust devils wind with few observation sites. Though only one observation site enables us to determine the discharging location, two or three sites improve the accuracy significantly. This measurement also contributes to the studies both on the crust and the upper atmosphere. We propose a very simple and promissing instrumentation set for the DC and AC electromagnetic observation making use of MELOS lander.

Keywords: Mars, surface, atmospheric electricity, dust devil, electromagnetic wave

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-21 Room:103 Time:May 25 15:45-16:00

Ionospheric Seasonal Variation in Martian Equatorial Region

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Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) is a multi-frequency, synthetic-aperture, orbital sounding radar onboard Mars Express which was launched into an elliptic orbit with an inclination of 86.35 deg on 25 Nov 2003. By analyzing the surface echoes of MARSIS, Safaeinili proposed a method to calibrate the ionospheric effect and estimate the total electron content (TEC), peak electron density and neutral atmosphere scale height near the ionospheric peak properly. Using this method to collect TEC of Martian ionosphere over one Martian year from MARSIS, we have found TEC of ionosphere in Martian Equatorial Region is seasonal changed, and the changing trend is correlated with the seasonal cycle of carbon dioxide. As we know, in the lower ionosphere, photoelectron ionization is significant and makes a contribution of 20˜30% to the total ionization rate [Nier and McElroy, 1977]. Even though CO_2 is the major atmospheric constituent of Mars at low altitudes and CO_2^+ ions are the primary ions produced below 100 km, O_2^+ ions are dominant at low altitudes (<260 km) because most of the CO_2^+ ions are broken down into O_2^+ ions through a subsequent ion-neutral reaction ($CO_2^+ + O \rightarrow O_2^+ + CO$). In a word, CO_2 is vaporized from polar cap, then photo-ionized to be CO_2^+, O_2^+ etc. These charged particles are main ions of Martian ionosphere, and interact with solar wind directly. As solar wind flows past Mars, significant amounts of ions are taken away. It means that oxygen dissociated from CO_2 escape from Martian atmosphere. Based on MARSIS TEC data, the amplitude of TEC changing is about 10^2 per m^2 which affects the oxygen escape speed.

Keywords: Mars, TEC, Carbon Dioxide

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS002-22 Room:103 Time:May 25 16:00-16:15

MHD simulations of the cold ion escape from the ionospheres of Mars and Venus

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Ionospheric flow channels and escape of cold ions from the ionospheres of Mars and Venus are investigated using a comprehensive magnetohydrodynamic (MHD) model of the solar wind interaction with the ionospheres of Mars and Venus. The model successfully describes the structures, dynamics, and energetics of both the solar wind and the planetary ionosphere regions. The model shows a complex 3-D flow pattern of the ionospheric plasma, forming large-scale four vortex structures on the nightside and escape channels through the magnetotail region. We also compare our numerical results with recent observations of the Kelvin-Helmoltz wave-like signatures obtained by the magnetometer onboard Venus Express. We show the importance of the viscous process in forming a complex flow pattern in the ionosphere and subsequent escape channels.

Keywords: Solar wind interaction, Mars, Venus