[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-PS 惑星科学

2019年5月27日(月) 9:00 ~ 10:30 | A03 東京ベイ幕張ホール

## [P-PS05] Recent advances of Venus science

コンビーナ:佐藤 毅彦(宇宙航空研究開発機構・宇宙科学研究本部)、堀之内 武(北海道大学地球環境科学研究院)、山本 勝(九州大学応用力学研究所)、Kevin McGouldrick(University of Colorado Boulder)、座長:Takeshi Horinouchi

Akatsuki, being in Venus orbit since December 2015, has acquired a volume of high-quality data, unveiled many new phenomena and is allowing researchers to investigate the underlying mechanisms. As the data accumulate, numerical models and theories are being advanced as well. We are no doubt living in the new golden era of Venus studies. This session invites papers of the new scientific results with Akatsuki data and the latest results of theoretical and numerical works. We expect participants of this session share the latest research results through presentations and discussion.

9:00 ~ 9:15

[PPS05-01] **Super-rotation of Venusian atmosphere in the equatorial region may be caused by the density driven separation**

*Adhithiyan Neduncheran[1]、Ugur Guven[1,2]、Ananyo Bhattacharya[3] (1.University of Petroleum and Energy Studies, India、2.United Nations Centre for Space Science and Technology Education in Asia and the Pacific、3.Sardar Vallabhbhai National Institute of Technology,India)

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9:15 ~ 9:30

[PPS05-02] Comparison of horizontal distributions of temperature and UV absorbers at the Venus cloud-tops

*河瀬 慎一郎[1]、田口 真[1]、福原 哲哉[1]、Yeon Joo Lee[2]、山崎 敦[3,4] (1.立教大学、2.マックスプランク太陽系研究所、3.宇宙科学研究所、4.宇宙航空研究開発機構)

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9:30 ~ 9:45

[PPS05-03] Orographic Gravity Waves in the Venus Atmospheric

*鈴木 杏那[1]、高木 征弘[1]、前島 康光[2]、安藤 紘基[1]、杉本 憲彦[3]、松田 佳久[4] (1.京都産業大学、2.理化学研究所 計算科学研究機構、3.慶應大学、4.東京学芸大学)

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9:45 ~ 10:00

[PPS05-04] Atmospheric structures simulated by T21 and T63 Venus GCMs with radiative transfer

*山本 勝[1]、池田 恒平[2]、高橋 正明[2] (1.九州大学応用力学研究所、2.国立環境研究所)

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10:00 ~ 10:15

[PPS05-05] あかつき/LIR観測により同定された金星雲層高度における熱潮汐波が作る温度擾乱構造

★招待講演

*神山 徹[1]、田口 真[2]、福原 哲哉[2]、今村 剛[3]、二口 将彦[4]、山田 武尊[2]、秋場 聖浩[2]、Yeon Joo Lee、佐藤 隆雄[7]、村上 真也[5]、はしもと じょーじ[6]、佐藤 毅彦[5]、中村 正人[5] (1.産業技術総合研究所、2.立教大学、3.東京大学、4.東邦大学、5.宇宙航空研究開発機構、6.岡山大学、7.北海道情報大学)

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10:15 ~ 10:30

[PPS05-06] From Venus to Mars: viewpoint of comparative meteorology

★Invited Papers

*今村 剛[1]、小郷原 一智[2]、中川 広務[3]、青木 翔平[3] (1.東京大学大学院　新領域創成科学研究科、2.滋賀県立大学工学部、3.東北大学大学院　理学研究科)

# Super-rotation of Venusian atmosphere in the equatorial region may be caused by the density driven separation

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On Venus, the clouds move nearly 60 times faster than the rotation of the planet. Super-rotation of the Venusian atmosphere is an intriguing phenomena and the reasons are still unclear. The super-rotation is possibly due to Venus being tidally locked to Sun as a consequence of which the planet experiences maximum heating in the equatorial zones causing meridional flows in the lower latitudes. The latent heat trapped by the Carbon dioxide gradually rises above due to its increased kinetic energy, which increases the motion of the cloud layers over time. Previous works done shows that the clouds are highly unstable in the altitude ranging from 49-55Km and below 30Km as per *Zasova et al* 2006 (doi:10.1016/j.pss.2007.01.011 ). This work shall put forth a possibility of density driven separation of cloud layers and its viscosity which helps in the super-rotation of the clouds. Similar hypothesis were presented by *Lebonnois et al* 2017 (DOI: 10.1038/NGEO2971). Using the known densities of atmospheric constituents, and applying the principles of viscosity and fluid dynamics, a simulation in COMSOL Multiphysics is done and analyzed for the flow behavior in the atmospheric layers ranging between 20Km and 80Km with respect to it's horizontal distance. The possible reasons regarding the flow will be discussed considering the solar convection in the equatorial region.

Keywords: Venus, atmosphere, super-rotation, clouds, flow simulation

# Comparison of horizontal distributions of temperature and UV absorbers at the Venus cloud-tops

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Venus is the nearest neighbor planet, which has a size similar to that of the earth. However, unlike the earth, Venus is covered with thick - clouds floating at 45-70 km altitudes (Nakamura et al. 2011). It is considered that the clouds are photochemically generated by oxidation of and . In the visible region, light reflected by the clouds are poorly absorbed and few structures are noticeable. On the other hand, in the ultraviolet (UV) region, inhomogeneity of albedo has been identified to be inhomogeneous distribution of UV absorbers above the layer of UV scattering. It has been identified that in the Venusian atmosphere absorbs light in the wavelength region between 200 nm and 320 nm, but chemical species responsible for the absorption in the wavelength region longer than 320 nm is still unidentified. and are candidates (Perez et al. 2018). The UV absorbers play an important role in the atmospheric dynamics, controlling vertical thermal stability by heating at the top of convection layer. The dynamics may feedback the distribution of the UV absorbers by transport of them from the lower atmosphere. Details of the chemical and dynamical coupling are still unknown.

We analyzed images obtained by the Longwave Infrared Camera (LIR) and Ultraviolet Imager (UVI) onboard the Venus orbiter Akatsuki. LIR takes images of thermal radiation in the wavelength range of 8-12 μm emitted from the cloud-tops (Fukuhara et al., 2011). Temperature distributions are derived from the images. Disturbances seen in the temperature distributions are thought to be caused by atmospheric waves and tides, changes in the cloud-top altitude and adiabatic heating and cooling due to convection, direct heating by the UV absorbers, and so on. UVI takes images of the solar radiation reflected by the clouds with narrow bandpass filters centered at the 283 and 365 nm wavelengths, which correspond to the absorption bands of and unknown absorbers (Yamazaki et al., 2018).

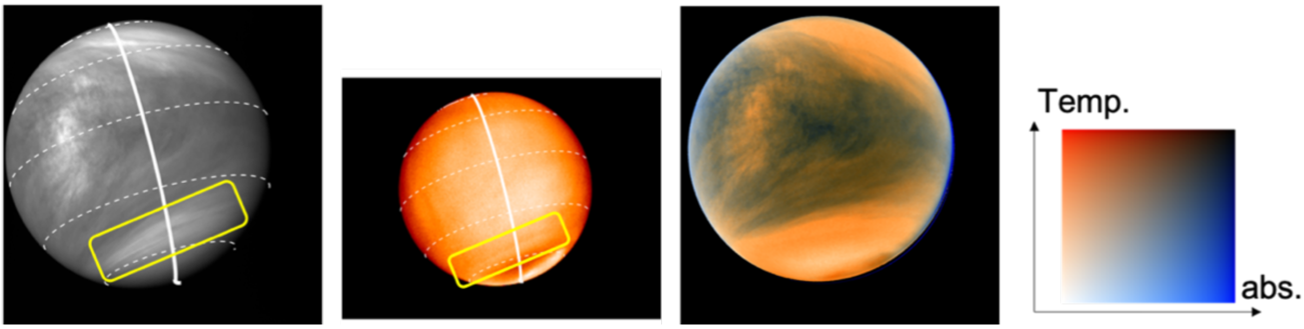
Observations at 365 nm often find clouds with a little radiation in the middle latitudes. Such clouds with low radiation (bright) are covering on the clouds with high radiation (dark). The bright clouds are hard to receive the supply of UV absorbers from the lower layer (Titov et al., 2008). We found such bright distributions in the middle latitudes of images taken by LIR and UVI. Examples (on January 26, 2017) are shown in figures. The fact that we can see the similar distributions at different wavelengths means that two cameras observe clouds almost the same altitude. Therefore, we are studying of the dynamics of cloud top distributions at middle latitudes to use data taken by LIR and UVI.

We converted the UV radiation obtained into the absorption rate. Furthermore, we compared by combining the absorption rate and the temperature. The combined image is displayed more reddish when the temperature is higher and it is displayed more blueish when UV absorption rate is higher. Example are shown in figures. The figure is displayed blackish in the equatorial region and whitish in the polar region. In the middle latitudes where we pay attention, the temperature is high and the amount of absorption is small, so it is displayed reddish. In this presentation, we will introduce some examples like this, and will present relationships between temperature and , temperature and unknown absorbers.

As a next step, we will further study the relationship between temperature and UV absorbers for each latitude and local time, and will clarify what atmospheric dynamics is occurring at the cloud top.

キーワード：金星、あかつき、未知紫外吸収物質
Keywords: Venus, Akatsuki, unknown UV absorber



# Orographic Gravity Waves in the Venus Atmospheric

*鈴木 杏那[1]、高木 征弘[1]、前島 康光[2]、安藤 紘基[1]、杉本 憲彦[3]、松田 佳久[4]
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Fast zonal winds called “super-rotation” are predominant globally in the Venus atmosphere, whose wind speed reaches ~100 m/s at ~70 km level (Schubert et al., 1980). Based on the zonal winds inferred from UV cloud images taken by the Venus Monitoring Camera onboard the Venus Express orbiter, Bertaux et al. (2016) pointed out that the zonal wind at ~70 km might be decreased by about 20 m/s over the Aphrodite terra, and suggested that the gravity waves generated by the Venus topography propagate upward, breaking at the cloud levels, giving their momentum to the atmosphere and decreasing of zonal wind. Young et al. (1987, 1994) numerically investigated the excitation and propagation processes of the gravity waves. Their results show that the gravity waves with horizontal wavelengths of 50 –800 km can propagate to the cloud levels if the zonal wind near the surface is of 2.2–3.0 m/s. However, the momentum transfer by the gravity waves is not examined. In the present study, we investigate the gravity waves in the Venus atmosphere with a focus on their momentum transfer using a cloud resolving numerical model named Cloud Resolving Storm Simulator (CReSS). Our preliminary results suggest that the orographic gravity waves can propagate upward and reach the cloud levels, as shown by Young et al. (1987, 1994). We will examine the momentum transfer by the gravity waves and discuss its effect on the super-rotation.

キーワード：金星大気、地形性重力波
Keywords: Venus atmosphere, orographic gravity wave

 

# Atmospheric structures simulated by T21 and T63 Venus GCMs with radiative transfer

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Radiative forcing and topography are important in the formations of the thermal and wind structures on Venus. The surface topography forces stationary waves, which induce large-scale stationary bow-shaped wave pattern (Fukuhara et al. 2017) and conspicuous variation of cloud-top zonal flow (Bertaux et al. 2016) over the Aphrodite Terra. The topographical and radiative effects on Venus’ atmosphere general circulation have been investigated using a T21L52 Venus AGCM at Atmosphere and Ocean Research Institute, Univ. Tokyo (Ikeda 2011). Our Venus GCM with the topographical data and radiative code simulated solar-locked and geographical atmospheric structures on Venus (Yamamoto et al. 2019). The model reproduced the wind structure near the subsolar point and the slowness of zonal wind over the Aphrodite Terra. Furthermore it showed that (1) the sub-rotation is formed near the surface in and around high land and mountains, (2) weakly stable layer is formed at 10-20 km at low latitudes, and (3) the zonal wind is weakened at the cloud top over the Aphrodite Terra. The third result implies that the negative wind deviation of the topographically forced stationary wave produces the slowness of the cloud-top zonal wind around the Aphrodite Terra. The GCM with the radiative code estimated the heat budget in the lower and middle atmospheres and reproduced the static stability similar to the observation. For the simulated zonal-mean structure, an equatorial fast flow of ~90 m/s and mid-latitude jets of ~120 m/s are formed around the cloud top. A poleward flow of >8 m/s is formed above the cloud layer, where the imbalance between solar and infrared radiative heating is large. Around the cloud top where the solar radiative heating balances the infrared one, a poleward flow is small (~1 m/s) and confined within the equatorward flank of the jet core. In and around the jet core, indirect circulations are formed by the eddy heat fluxes owing to the thermal tide and baroclinic waves. In solar-fixed coordinates, differences are significant between the zonal and dayside averages of the meridional wind and its related fluxes within the cloud layer. This suggests that we must carefully estimate the zonal-mean Hadley circulation, eddy momentum flux, and eddy heat flux from the one-side hemisphere. Most of the abovementioned features obtained from the T21 GCM are also seen in the T63 GCM. In this presentation, under the realistic thermal and topographical condition, the effects of the high resolution are also discussed. If we have room or time in this presentation, we briefly show the momentum budget, together with the heat budget shown in Yamamoto et al. (2019).

# あかつき/LIR観測により同定された金星雲層高度における熱潮汐波が作る温度擾乱構造

# Thermal-tides structure at the cloud level of Venus derived from Akatsuki/LIR observations

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Atmospheric acceleration due to thermal-tides excited in the cloud layer has been considered as one of main contributors for maintaining the atmospheric super-rotation in Venus, where zonal wind speed of the atmosphere at the cloud top (~70 km) rotates more than 60 times faster than the rotation speed of the solid body of Venus. The structures of the thermal-tides have been confirmed firstly in a temperature field and in zonal and meridional wind fields at the cloud top level by tracking cloud motions in several Venus exploration missions. In numerical studies, it has been confirmed that the thermal-tides structure is composed of diurnal, semi-diurnal, and higher frequent components which enhance at different altitudes and latitudes. Since they may contribute atmospheric acceleration according to their enhancement, observational monitoring should be important to understand what components of thermal-tides are dominant in different latitudes. On the other hand, there have been less observational studies about the latitudinal structures of thermal-tides in temperature fields due to time limitation for ground-based observations and limitation of spatial coverage for previous satellite observations.

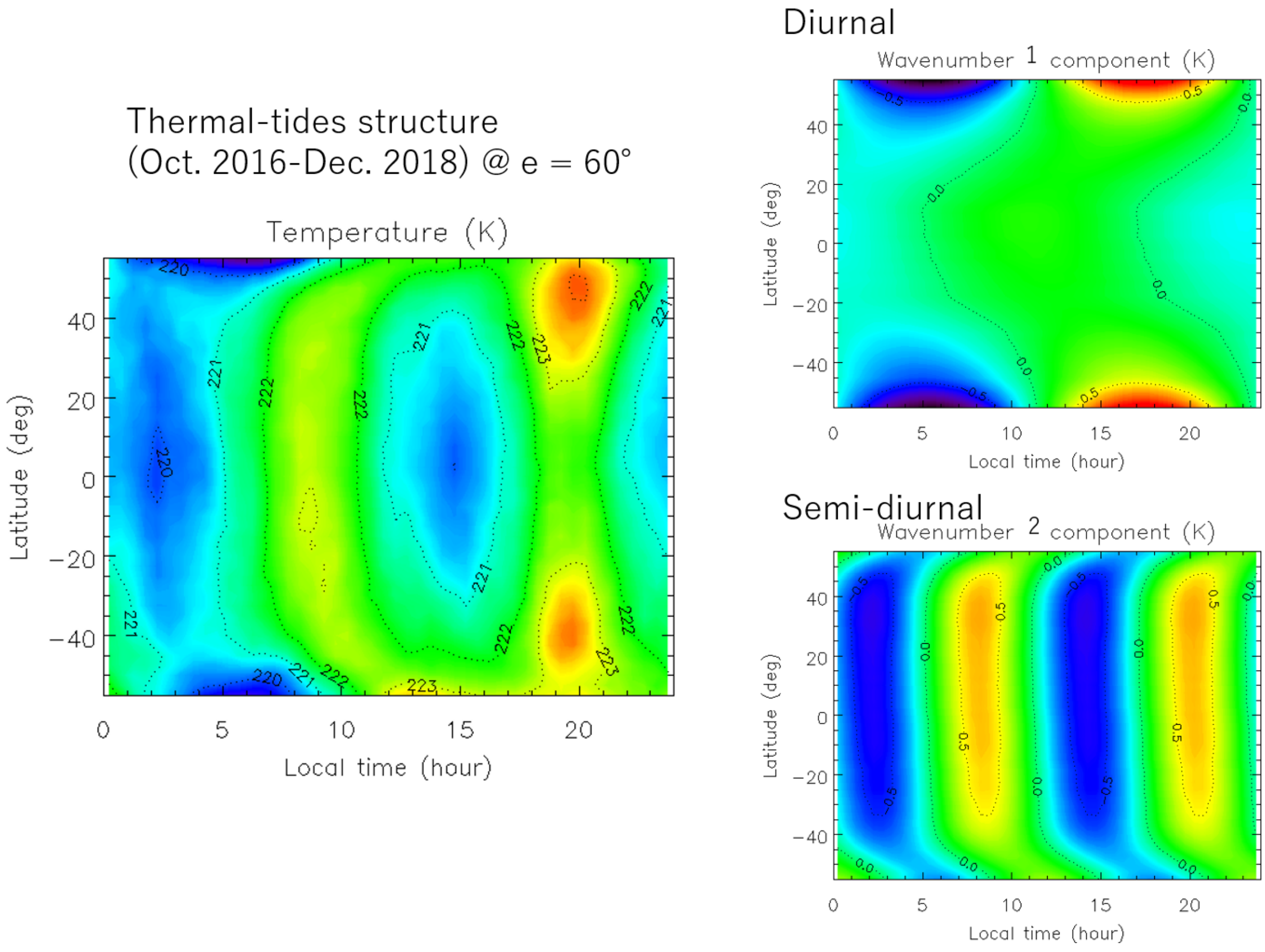
In this study, we investigated latitudinal profiles of diurnal, semi-diurnal, and higher frequent components of thermal-tides in the temperature field obtained from long-term observation data by Longwave Infrared Camera (LIR) onboard Akatsuski that catches thermal emission from Venusian cloud layer (60-70km). We used the LIR data from October 2016 to December 2018 in which LIR had been remained to be turned on to prevent unexpected temperature increasing in LIR images, and we selected a specified emission angle (60°) in the analysis to minimize emission angle dependence of a limb darkening effect.

Thanks to the global coverage of LIR observation in both dayside and night side, a global thermal-tides structure (local time-latitude coordinate) was firstly obtained by averaging the long-term LIR observation. By applying Fourier analysis to the thermal-tides structure, we found that the semi-diurnal component was clearly dominant in lower latitudes (< 30°) whereas the diurnal component became significant in higher latitudes (> 45°), and both diurnal and semi-diurnal tides showed almost equatorial symmetric profiles. These characteristics were consistent with a numerical expectation in a global circulation model by Takagi et al. (2018). In addition, the diurnal component showed clear phase tilting in mid-latitudes, which may

indicate latitudinal energy transportation due to the diurnal component, while the semi-diurnal and other components with higher wavenumbers did not show such clear phase tilting in low-mid latitudes.

In this presentation, we will provide the structures of each thermal tide components, and latitudinal profiles of their amplitudes and phases, and we will also discuss thermal-tides structures at different periods for more detail discussion about variability of the tides.

キーワード：金星、熱潮汐波、LIR
Keywords: Venus, Thermal tides, LIR



# From Venus to Mars: viewpoint of comparative meteorology

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The next Japanese planetary mission focusing on atmospheric science will be the Mars observation in the MMX (Martian Moons eXploration) mission. The spacecraft will enter a near-equatorial, high-altitude, circular orbit around Mars in 2025 and stay in orbit for 3 years. During this Mars-orbiting phase, the spacecraft will collect samples from Phobos and remotely observe Phobos, Deimos and Mars. Continuous, high-resolution, multi-wavelength, global observations of the Mars atmosphere enable monitoring of meteorological processes driving dust/water cycle in the atmosphere-surface system. The instruments used will be a near-infrared imaging spectrometer and multi-band cameras.

The Mars observation in MMX is considered a natural extension of the Venus orbiter Akatsuki. The observation sequence of MMX is similar to that of Akatsuki in that global images are acquired at short time intervals from an equatorial orbit similarly to Earth's meteorological satellites. From the viewpoint of comparative meteorology, Martian meteorology is contrasted with Venusian meteorology in many aspects. Examples include: superrotation on Venus vs. strong high-latitude jets on Mars; weak thermal forcing on Venus vs. strong thermal forcing on Mars; internal oscillation on Venus vs. seasonal cycle on Mars; wave-driven circulation on Venus vs. heat-driven circulation on Mars; slow convection on Venus vs. fast convection on Mars; uniform aerosols on Venus vs. variable aerosols on Mars; weak vertical coupling on Venus vs. strong vertical coupling on Mars. In order to maximize scientific achievements, feedbacks from Akatsuki to MMX are required.

キーワード：金星、火星、気象学
Keywords: Venus, Mars, meteorology