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MTT41-01 会場:203 時間:5 月 26 日 09:00-09:15

インフラサウンド及び地震波動からみた極域の多圏融合物理現象
Interdisciplinary physical phenomena within multiple spheres in polar regions inferred from infrasound and seismic waves

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Several characteristic waves detected by seismographs in Antarctic stations have been recognized as originating from the physical interaction between the solid-earth and the atmosphere - ocean - cryosphere system surrounding the Antarctic and may be used as a proxy for characterizing ocean wave climate. A Chaparral type infrasound sensor was installed at Syowa Station (SYO; 39.6E, 69.0S), East Antarctica, in April 2008 during the International Polar Year (IPY2007-2008). Matching data are also available for this time period from the existing broadband seismic recorder located close by. Continuous infrasound data for 2008-09 includes background signals (microbaroms) with a broad peak in the wave period between the values of 4 and 10 seconds. Signals with the same period are recorded by the broadband seismograph at SYO (microseisms). This period band is identified as Double-Frequency Microseisms/baroms (DFM). The DFM has relatively lower amplitudes during winter. We suggest that this is due to the sea-ice extent around the coast causing a decreased ocean loading effect. In contrast, the Single Frequency Microseisms/baroms (SFM) with a peak in period between 12 and 30 seconds are observed under storm conditions, particularly in winter. On the infrasound data, stationary signals are identified with harmonic overtones at a few Hz to lowermost human audible band, which we suggest is due to local effects such as sea-ice cracking and vibration. Microseism measurements are a useful proxy for characterizing ocean wave climate, complementing other oceanographic and geophysical data. At SYO, continuous monitoring by both broadband seismograph and infrasound contributes to the Federation of Digital Seismographic Networks, the Comprehensive Nuclear-Test-Ban Treaty in the high southern latitudes, and the Pan-Antarctic Observations System under the Scientific Committee on Antarctic Research.
Keywords: infrasound, seismic waves, physical interaction, multi-spheres, polar regions

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南極昭和基地で観測された微気圧変動シグナルの長期トレンド
Long Term Trend of Infrasound Signals Observed at Syowa Station, East Antarctica

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Infrasound is sub-audible sound whose frequency range is about 3 mHz to 20 Hz. Because this frequency is common between atmospheric, oceanic and solid earth vibrations, those waves are interacting with each other and interaction itself generates infrasound. At polar region, cryosphere also play an important role for generation and propagation of infrasound. Last decade, for the purpose of monitoring nuclear tests, a global infrasound network is constructed by CTBTO. The CTBT-IMS infrasound network has 47 working stations (as of September 2014) and each station consists at least 4 infrasound sensors (arrayed observation), they can detect a some-kiloton TNT level atmospheric explosion in range of some 1000 kilometers. The network is almost enough for monitoring nuclear tests, but much sparse for detecting and analyzing in detail of natural infrasound phenomena. Especially at Antarctica, CTBT-IMS has only two stations and is most insufficient observation area.

The Japanese Antarctic infrasound observation started at April 2008 as one sensor pilot observation. A Chaparral-type infrasound sensor was installed at Syowa Station (SYO) in Lutzow-Holm Bay (LHB) of East Antarctica, as a part of the International Polar Year (IPY2007-2008). And then, following success of pilot observation, in austral summer in 2013, we extended one-sensor observation at SYO to 3-sensor arrayed observations, and installed a few field stations along the coast of the LHB.

In this study, we will show the trend of infrasound signals observed at SYO during whole observation period (2008 - 2014). Characteristic infrasound waves observed at SYO demonstrate physical interaction involving environmental changes in the Antarctic region. Continuous recording of infrasound, from April 2008 to present, clearly indicate existence of the background atmospheric vibration generated by ocean-atmosphere interaction (microbaroms) with peaks of 0.1 to 0.25 Hz observed during entire period. Because larger amount of sea-ice extending around the LHB near SYO suppress ocean wave, the microbaroms become weak during austral winter. Newly established SYO array clearly detected the propagating directions and frequency contents of the microbaroms from Southern Ocean.In addition, we found harmonic signals around lowermost human audible band, however, currently unclear how and what generating hamonic signals. Those signals are recorded under windy condition. Since our system has no mechanical resonance at those frequency ranges, we speculate that the characteristic harmonic signals are probably related to local surficial phenomena such as ice sheet vibration generated by katabatic winds.

Infrasound measurement at Antarctica could be a new proxy for monitoring a regional environmental change in high southern latitude. In such point of view, we will continue and improve the observations at and around SYO, Antarctica.

キーワード: インフラサウンド, 南極
Keywords: Infrasound, Antarctica

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重力音波により生成される中低緯度小規模沿磁力線電流と地上磁場および微気圧変動
SWARM observation of small scale field-aligned currents generated by acoustic waves and their signature on the ground

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ほぼ同一の極軌道上を 10-100 秒の時間間隔で飛翔した 3 機構成の精密磁場観測衛星 SWARM 打ち上げ直後 2 ヶ月間の観測データを用いることにより、CHAMP 衛星等も含め、これら低高度衛星によってほぼ常時中低緯度で観測される 20-30 秒周期の磁場振動が、微細な沿磁力線電流である事が確認できた。また、それらの時間変動のスケールがおおよそ 200 秒から 350 秒程度、あるいはそれ以下である事が見積もられ、原因が音波モードの大気重力波である事が推測される。一方、地上の磁場および微気圧観測からは、地表と熱圏の間の音波共鳴周期あるいは電離圏ダイナモ領域付近の重力音波カットオフ周期に近い周期帯に、振動がしばしば観測される。上記解析結果を示すと共に、これらの間の関連についても議論する。

キーワード: 重力音波, 電離層ダイナモ, 沿磁力線電流, SWARM 衛星, 微気圧振動, 磁場振動
Keywords: acoustic gravity wave, ionospheric dynamo, field-aligned current, SWARM satellites, micro-barometric oscillation, magnetic oscillation

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地震波によって励起されたインフラサウンドのイオノゾンデによる波面追跡と熱圏の電波-音波計測
Radio acoustic sounding of the thermosphere by ionosonde tracking of infrasound wavefronts launched by seismic waves

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It is well known that atmospheric waves excited by intense earthquakes induce ionospheric disturbances. At remote distances greater than ∼500 km, Rayleigh waves are the major source of infrasounds that propagate upward in the atmosphere. Acoustic waves interact with the ionospheric plasma through collision between neutral particles and ions. Ionospheric disturbances caused by Rayleigh waves near the low frequency part of the Airy phase (a period of several minutes) are detected as a change in the total electron content since the wavelength of induced acoustic waves in the thermosphere is comparable to the ionospheric slab thickness. On the other hand, Rayleigh waves near the high frequency part of the Airy phase (a period of several tens of seconds) cause distortion of ionogram traces, which is characterized by a multiple cusp signature (MCS). The vertical separation of the ledge corresponding to each cusp is the wavelength of the infrasound in the thermosphere. Thus, the MCS ionogram is considered to be a snapshot of the wave that propagates upward.

We conducted rapid-run operation of ionosonde with a frame rate of 1 min at Kazan, Russia. After the 2010 M8.8 Chile earthquake (epicentral distance was 15,162 km), ionospheric disturbances showing MCSs in ionograms were observed for several tens of minutes. The seismogram obtained at Obninsk near Moscow, Russia (epicentral distance was 14,369 km) recorded Rayleigh waves with a period of ∼17 s responsible for the ionospheric disturbances showing MCS (the seismogram was shifted by the time corresponding to the difference of epicentral distances between the two locations by assuming a Rayleigh wave speed of 3 km/s). The vertical wavelength of the acoustic wave launched by the Rayleigh waves was 8.5∼12 km in the thermosphere. The sound speed calculated by a model was 500∼700 m/s at the height of the bottomside ionosphere and wavefronts should propagate 30∼42 km upward during the intervals of ionograms, which is smaller than the bottomside depth of the ionosphere. Thus, we could track acoustic wavefronts between consecutive MCS ionograms.

This observation bears an analogy with radio acoustic sounding system (RASS), in which atmospheric perturbation induced by acoustic sounds is tracked by a radar technique and the sound speed (and corresponding virtual temperature) at high altitudes is remotely measured. In a like manner, we compared the sound speed estimated by the MCS analysis and that calculated by the MSIS thermospheric model. The determined sound speed (and corresponding temperature) was slightly higher than the model.

キーワード: イオノゾンデ, カスプ構造, 2010 チリ地震, レーリー波, インフラサウンド, 熱圏
Keywords: ionosonde, multiple cusp signature, 2010 Chile earthquake, Rayleigh waves, infrasounds, thermosphere

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MTT41-05 会場:203 時間:5 月 26 日 10:00-10:15

積雲対流による地上気圧変動の励起
Surface pressure variation excited by cumulus convection

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[はじめに]
固体地球は地震のないときにも振動しており、その自由振動を積雲から発生する音波が駆動している可能性があることが議論されている (中島・野津原, 2001; 島崎・中島, 2008 ほか)。この検討には音波を含めたすべての大気波動を近似なしに含む数値モデルが必要である。田島・中島 (2007) は、厳密な連続の式と状態方程式から気圧を予報する数値モデルである完全圧縮系陽解法の雲対流数値モデルを作成し、積雲の生成や降雨の様子、積雲から発生する音波について数値実験を行い、主に地球自由振動の励起と関連する非常に長い波長の成分について考察した。一方、近年、微気圧計のネットワークの展開（例えば、Nishida et al, 2006）により、大気擾乱や地震など、様々な現象と関連した気圧変動の把握が進んでいる。そこで本発表では、積雲が励起する気圧変動のうち、地上に置かれた微気圧計で観測されるであろう気圧変動について数値モデルにより調べる。

[数値モデルと実験設定]
完全圧縮系湿潤大気の鉛直水平二次元数値モデルを作成した。基礎方程式は差分法によって離散化した。水物質としては気相 (水蒸気) と液相 (雲水、雨水) のみを考え、各雲微物理過程は基本的に Kessler(1969) のバルクパラメタリゼーションに従う。拡散係数、粘性係数の計算は Klemp and Wilhelmson(1978) に従う。計算領域は水平方向に 20km、鉛直方向に 120km とし、格子間隔はともに 167m とした。計算領域の上端と下端で鉛直 流をゼロとし、水平方向には全ての変数について周期境界条件を与えた。また下部境界では、雨水をその量に比例して 吸い取るように設定してある。初期の温度には標準大気の気温高度分布 (U.S.Standard Atmosphere 1976) を用い、湿度 を地表面で 90%、高度 1km で 100%、高度 10km で 20%、高度 20km で 0 となるように水蒸気の高度分布を与えた。雲 水と雨水は初期には存在しないものとする。また水平風、鉛直風は初期にゼロとし、静力学平衡が成り立つものとする。 水蒸気を凝結させる擾乱を引き起こすために、地表から高度 1km に水平風の収束を強制する外力を与える。その大きさ は初期がゼロとし、その後徐々に大きくし、50 秒で最大値、その後は弱まって 100 秒でゼロように設定した。 計算は 0.1 秒のタイムステップで 6000 秒行なった。また、鉛直 1 次元線形モデルを作成し、2 次元完全圧縮系モデルから計算した非線形項などのソース項を加えて大規模な地表面 気圧変動の励起源を求める計算を行った。

[結果]
完全圧縮系モデルによって典型的な積雲のライフサイクルが再現されることが確認されたので、地球自由振動の励起源と対応付けられる水平平均地表面気圧を調べた。水平平均気圧変動は、積雲の生成消滅に対応する 1 時間程度の時定数をもつ長周期の変動と、数十秒ないし数百秒の周期をも つ短周期振動の両方を含んでいることがわかった。さらに、二次元計算のでの水平平均気圧変動を鉛直 1 次元線形モデルでの気圧変動と比較した結果から、地表面気圧変動の長周期成分の起源が主に凝結に伴う水蒸気量の変化および雨や 雲による引きずりであること、そして、短周期成分の起源が主に潜熱放出であることがわかった。
一方、水平平均しない気圧変動には、より短周期成分が見られる。当日は、これについても詳細に報告する。

キーワード: 積雲, 微気圧変動, 地球自由振動, インフラサウンド
Keywords: cumulus convection, microbaroms, free oscillation, infrasound

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インフラサウンド観測で捉えられた極端気象現象 -雷について-
Severe weather phenomenon detected by pressure sensors -thunderstorm-

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Recently, meteorological disturbances and localized concentrated heavy rainfall drastically developed thunderclouds, which can be attributed to global warming, cause disasters like debris. In order to detect such a localized concentrated heavy rainfall, X-band polarimetric radar information network system (XRAIN) is gradually deployed and operated in Japan. The radar system can detect regional scale distribution of cloud water and growing process of localized concentrated heavy rainfall. However, spacial scale of thunder and tornado is smaller than the resolution of the radar system.

Infrasound signal is generated by rapid compress atmospheric such as thunder and vortex rotation by wind. Infrasound array system can detect arrival direction, but it is difficult to estimate the distance from source to observation point only one Infrasound array system.

Many meteorological disturbance in combination with thunder occurred on the Kanto region in the summer of 2014. In order to evaluate meteorological disturbance more accurately, we set up new Infrasound array system in Saitama Prefecture in addition to the existing in Chiba Prefecture.

The back azimuth of signals at two Infrasound array system intersect, and the place was high precipitation intensity on XRAIN image.

キーワード: インフラサウンド, 極端気象現象, XRAIN, 雷
Keywords: Infrasound, severe weather phenomenon, XRAIN, thunderstorm