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RISR と OMTI による極冠オーロラの観測
An Observation of Polar Cap Aurora with RISR and OMTI: A Feasibility Study for EISCAT_3D

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One of the primary scientific objectives of the planned EISCAT_3D would be ”3D imaging of aurora”, especially 3D imaging of dynamically moving auroral arcs at the time of substorm expansion phase onset. In order to discuss the specification of the EISCAT_3D system, we have to know how such an effort of 3D imaging of aurora is being made by using currently-working IS radar systems. For this purpose, we introduce an event of isolated auroral arc in the polar cap region which was simultaneously observed by an all-sky imager of OMTIs (Optical Mesosphere Thermosphere Imagers) and RISR (Resolute Bay Incoherent Scatter Radar) at Resolute Bay, Canada (74.7 N, 265.0 E, 82.9 MLAT) in winter/2009. By using the data during this event, we visualized the plasma structure near the arc in 3D fashion. In particular, we tried to reproduce the 3D structure of electric field and corresponding electric current through a quantitative estimation of horizontal plasma velocity along the arc. As a result, ion velocity around the arc was found to show a shear reversal flow across the arc at 200-400 km altitudes; -1500 m/s on the dusk-side of the arc and 1000 m/s on the other side of the arc. This reversed flow corresponds to an electric field (i.e., Pedersen current) structure converging towards the center of the arc. Such a converging Pedersen current is consistent with upward field-aligned currents (FACs) within the arc which are possibly carried by precipitating electrons leading to the generation of the arc. Possible 3D structure of electric field and electric current including FAC around the arc will be discussed as a feasibility study for the EISCAT_3D system.

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一般化オーロラトモグラフィの EISCAT_3D プロジェクトへの応用
Application of Generalized Auroral Computed Tomography to the EISCAT_3D project

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Aurora Computed Tomography (ACT) is a method for retrieving three-dimensional (3-D) distribution of auroral luminosity from auroral images obtained simultaneously by the multi-point observation. As a next step of the ACT, we have developed Generalized - Aurora Computed Tomography (G-ACT) that reconstructs the energy and spatial distributions of precipitating electrons from multi-instrument data, such as ionospheric electron density from the EISCAT radar, cosmic noise absorption (CNA) from imaging riometer, as well as the auroral images. This method is compatible with 3-D ionospheric data observed by the EISCAT_3D radar, because the tomography method essentially assumes that the observational data are the projection of the 3-D data.

In this study, we examine how the G-ACT method can contribute to the EISCAT_3D project by numerical simulation. We first obtained auroral images observed by ALIS (Aurora Large Imaging System) and the electron density distribution observed with the EISCAT_3D radar by assuming spatial and energy distribution of incident electrons and then applied the G-ACT to these data. The results showed a possibility that the G-ACT can interpolate the electron density distribution observed with the EISCAT_3D radar at a higher spatial resolution. On the other hand, the 3-D aurora distribution reconstructed from only optical images was improved by a use of the EISCAT 3-D data. Furthermore, we suggest where new imagers should be installed for simultaneous observation with the EISCAT_3D radar.

キーワード: オーロラトモグラフィ, EISCAT_3D, 逆問題, 3 次元構造, オーロライメージャ, 電離圏電子密度
Keywords: aurora tomography, EISCAT_3D, inverse problem, 3 dimensional structure, aurora imager, ionospheric electron density

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EISCAT レーダートロムソ観測所における 2013 年 3 月までの STEL 光学観測結果と EISCAT_3D への貢献
Report of the STEL optical observation at the Tromsoe EISCAT radar site by March 2013 and the contributions to EISCAT_3D

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太陽地球環境研究所（Solar-Terrestrial Environment Laboratory; STEL）は欧州非干渉散乱（European Incoherent Scatter; EISCAT）レーダーがあるノルウェーのトロムソ（北緯 69.6°、東経 19.2°）で 10 年以上に渡り光学観測を実施してきた。トロムソは欧米・アジア諸国が様々な光学・電波観測装置を設置し、EISCAT レーダーを軸とした国際共同観測研究を展開する世界最大級の観測拠点である。2013 年 1 月現在、我々はトロムソ観測所に以下に述べる 5 台の光学観測装置を設置し、10 月から翌 3 月の約半年間、自動観測とともに共同研究者からの要請に応じた観測モードで運用を行っている。尚、これら光学観測装置以外にナトリウムライダーが 2010 年 10 月から稼働している。これについては別に報告する。

1. 3 波長フォトメータ
1997 年 1 月に最初のキャンペーン観測を実施後、2001 年 10 月に自動運用を開始した本装置は現在 3 つの光学フィルター（427.8 nm, 630.0 nm, 557.7 nm）を持ち、20Hz サンプリングでデータを取得する。2010 年 10 月に運用・データの自動処理システムを更新した。常に磁力線方向に固定した観測を行い、EISCAT UHF レーダーの主要観測モードの一つである CP-1 モード（同じく磁力線方向にアンテナ方向を固定した観測）とほぼ同じ空間を同時に観測することができる。

2. 天候・オーロラ観測用デジタルカメラ
対流圏高度の雲の発生状況を把握することは、光学観測データの解析にとって必須事項である。光学フィルターを通した単色画像では天候を判別しにくく、デジタルカメラで撮影されるカラー画像がより適している。そこで 2001 年 10 月からデジタルカメラによる自動観測を開始した。撮影画像は天候確認だけでなく、磁力線付近のオーロラ微細構造などオーロラ形態情報の提供も兼ねている。

3. プロトン全天カメラ
2006 年 10 月から自動運用を開始した本装置は、下向き沿磁力線電流の発生領域における電離圏応答を捉えることを目的に設置された。上向き沿磁力線電流の発生領域（オーロラアーク発生領域に相当）に近接するオーロラ発光が弱く、電離圏電子密度が周辺より極端に低い領域には、下向き沿磁力線電流と磁場に垂直な電場が発生すると考えられている。これら電流回路の連続性を維持するために下向き沿磁力線電場が形成され、磁気圏からのプロトン降込みが誘導される結果、プロトン発光（486.1 nm）が期待される。これまでの観測で数例だがこの仮説を裏付ける観測結果が取得されている。

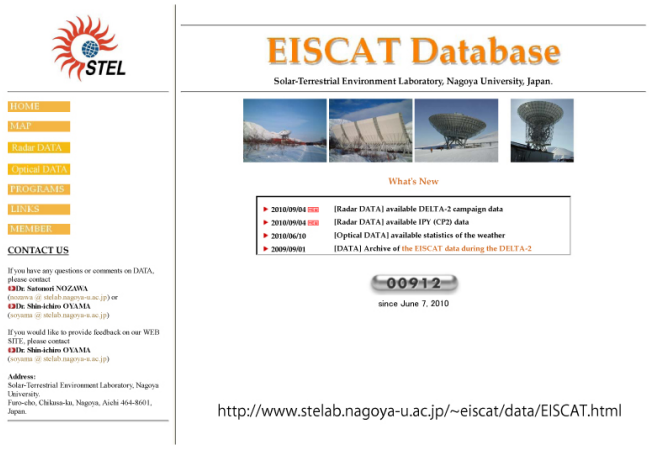
4. 多波長全天カメラ
オーロラや大気光を観測する目的で 2009 年 1 月に設置された本装置は、6 種類の光学フィルターが装着されたホイールを備え、積分時間や観測波長の順番などを任意に設定できる自動観測プログラムによって制御されている。現在保有する光学フィルターの波長は、557.7 nm、630.0 nm、OH バンド、589.3 nm、572.5 nm、732.0 nm である。

5. ファブリペロー干渉計（Fabry-Perot interferometer: FPI）
多波長全天カメラ（上記 4）と同時にトロムソ観測所に設置された本装置は、視野角約 4° の狭視野タイプの装置であり、3 種類の光学フィルターを装着したホイールを持つ。装置上部にはスカイスキャナーと呼ばれる回転モーター付ミラーがあり、観測プログラムでホイールとスカイスキャナーを制御することで、観測波長やその選択順序と積分時間、視線方向を科学目的に合わせて任意に設定することができる。観測される物理量は中性大気の風速と温度である。

これらの光学観測装置は、EISCAT レーダーをはじめ様々な観測装置との共同観測実験に利用されてきた。最初の装置が自動観測を始めて以来、稼働期間は太陽活動周期の 1 サイクルに近く、超高層大気の長期変動研究やイベント解析を行う上で貴重なデータセットが整備された。これまでに蓄積された観測データのクイックルックはウェブページで公開されている（www.stelab.nagoya-u.ac.jp/~eiscat/data/EISCAT.html）。今後も全装置の自動観測を継続し、太陽活動極大期に計画されている様々な観測実験に参画し、国内外の共同研究者の研究活動に寄与していく。特に EISCAT_3D との同時観

測は、時間的・空間的に激しく変化するオーロラ現象の理解を進める上で重要なデータセットを提供できると期待される。本発表では、観測状況を報告するとともに EISCAT_3D との同時観測について議論する。

キーワード: オーロラ, 大気光, 光学装置, 電離圏, 熱圏, 極域
Keywords: Aurora, Airglow, Optical instrument, Ionosphere, Thermosphere, Polar region



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極域電離圏における N2+発光とイオン上昇流のれいめい衛星-EISCAT レーダー同時観測
Coordinated observation between Reimei and EISCAT radar of N2+ emission and ion upflow in the polar topside ionosphere

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The upflow and outflow of heavy ions, such as N2+ and NO+, has been examined with immense interests since it is considered that heavy ions hardly escape from terrestrial gravity. It is considered that the generation process of N2+ outflow is the charge exchange between O+ and N2 at topside ionosphere. Recently, optical measurement data taken by a satellite showed N2+ 1st negative band emissions in the sunlit region suggesting the existence of N2+ upflow. To clarify the process of ion upflow, we carried out the coordinated observations between the Reimei satellite and the EISCAT/ESR radar during the winter solstice periods from 2005 to 2012, except for 2011 due to the problem on Reimei attitude system.

The field-of-view (FOV) of the multi-spectral auroral camera (MAC) on Reimei was directed toward the earth's limb in order to observe the height profile of N2+ emission intensity produced by resonant scattering. In this case, the altitude resolution and range in the image data obtained with Reimei/MAC are approximately 5 km and 300 km, respectively. N2+ emission image was taken with every 1 second. On the other hand, ion upflow speeds near the FOV of MAC are simultaneously observed by the EISCAT/ESR radar with the fast scan mode or fixed mode toward the magnetic zenith. In the scan mode, the azimuthal scan range is 120 degrees centering the geomagnetic north direction, and time resolution is about 3 min.

Using the Reimei data, we examined the relationship among N2+ 1st negative and OI green line emissions, ion upflow and geomagnetic activity. We found good correlation between N2+ emission intensities at 300 and 400km altitude and Kp indices. At these altitudes, N2+ emission intensities were 100-600R greater than OI intensities when Kp was greater than 3+. This suggests that N2+ density increase, or ion upflow occurs in the topside/upper ionosphere when geomagnetic activity increased.

From the statistical analysis based on the coordinated measurement data between Reimei and EISCAT/ESR radar, we found no significant relationship between ion up/down flow and and N2+ emission. Considering the fact that the dayside heating region (cusp/cleft and auroral oval) is expected to be shifted toward lower-latitudes, far from the ESR-site during the disturbed conditions, it is suggested that N2+ enhancement measured by Reimei was not generated locally at the field line threading Reimei, but may be transported from the dayside heating region. In this presentation, we will present the recent results on the coordinated observations, and give the future subject for the EISCAT-3D project.

キーワード: れいめい, EISCAT, イオン上昇流, オーロラ, 電離圏
Keywords: Reimei, EISCAT, ion upflow, aurora, ionosphere

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EISCAT_3D を用いたイオン上昇流/流出の研究
Study on ion upflow and outflow with EISCAT_3D

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An important phenomenon of magnetosphere-ionosphere coupling is the formation of upwelling ions in the topside polar ionosphere. These upflows can be a significant loss of atmospheric gasses into interplanetary space and a significant source of magnetospheric plasma, which may also affect the dynamics of the magnetosphere. Key processes for upward ion flows in the topside ionosphere are suggested to be frictional heating, ambipolar diffusion driven by a heated electron gas, and transverse ion acceleration produced by plasma waves. It is critical to determine the relative importance of the different mechanisms in operation and to understand the 3D distribution and composition of the upflowing ions and neutrals. Moreover, there are several transitions of upflowing ions, for examples, from chemical to diffusion dominance at 500-800 km altitude, from subsonic to supersonic flow at 1000-2000 km altitude, and from collisional to collisionless region at 1500-2500km altitude. EISCAT_3D is one of the most suitable measurements to investigate such transitions because of its wider height coverage (up to about 2000 km) along the field line. EISCAT_3D will have more transmitter power density and higher sensitivity than those of the current Tromso UHF radar, and will give information of accurate thermal ion velocity, upward flux, and ion composition (O+, H+, and hopefully NO+). In this paper, potential investigations of ion upflow and outflow using the EISCAT_3D are shown, and desirable specifications of the EISCAT_3D are discussed.

キーワード: 極域電離圏, EISCAT_3D, イオン流出
Keywords: Polar ionosphere, EISCAT_3D, ion outflow

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EISCAT トロムソサイトにおける Na 共鳴散乱ライダーと EISCAT レーダーの連携観測
Coordinated observations with Na resonance scattering lidar and EISCAT radar at the EISCAT Tromsoe site

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We have been operating a sodium (Na) resonance scattering lidar at the EISCAT Tromsoe site (69.6N, 19.2E) since 2010, in cooperation with the EISCAT radar. The Na resonance scattering lidar is capable to measure neutral temperature, neutral wind velocity, and sodium density. On the other hand, as a well-known fact, the EISCAT radar is a powerful tool for ionospheric measurements. Thus coordinated observations with the Na resonance scattering lidar and EISCAT radar will be an important key to resolve the atmosphere-ionosphere coupling process. In this presentation, we introduce the Na resonance scattering lidar observations at the EISCAT Tromsoe site, and then report some recent results, such as sporadic Na/E-layer event which is an aspect of ion-neutral dynamical and chemical interactions. Hopefully these results would be good examples to discuss possibilities of further collaborative observations using the Na resonance scattering lidar and the EISCAT/EISCAT 3D.
Keywords: Na resonance scattering lidar, EISCAT/EISCAT_3D, Tromsoe, Sporadic Na layer, Sporadic E layer

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EISCAT_3D と GCM シミュレーションによる極域超高層大気の研究
Polar aeronomy with EISCAT_3D and GCM simulations

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The EISCAT radar system has had great contributions to probing the polar upper atmosphere in collaboration with observations from optical and radar instruments, magnetometers, rockets, and satellites more than 30 years. For the next stage, the EISCAT radar system seems to be still expected to undertake a role of the research center for the auroral atmosphere. The global warming and the resultant cooling in the upper atmosphere are one of the most important issues for aeronomy in the 21st century. In order to understand the long-term variations of the upper atmosphere, continuity of observations is necessary and the EISCAT observations will have great contributions to the topics. Challenges to unknown phenomena are also important for the new EISCAT radar system (EISCAT_3D). For example, the EISCAT_3D system and some instruments installed around the site will capture the turbulence which would be generated by breaking of atmospheric waves. This comprehensive monitoring of the atmospheric phenomena and space weather will enable us to predict the weather in the upper atmosphere with GCM simulations. In this presentation, we will show our research activity to date and future research plans with EISCAT_3D and GCM simulations.

キーワード: 極域, 超高層大気, レーダー, GCM
Keywords: polar region, upper atmosphere, radar, GCM