White paper on collaborative observations between ERG and EISCAT

written by
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Updated on November 27, 2016

History of this manuscript:

2016-09-12: Y. Ogawa prepared the first draft of the white paper after discussion with Y. Miyoshi and I. Shinohara.

2016-09-12: Y. Miyoshi modified the draft of the white paper.

2016-09-13: K. Shiokawa commented on the draft, and Y. Ogawa modified it.

2016-09-14: K. Hosokawa prepared an updated figure for the draft.

2016-09-14: Plans of the ERG-EISCAT collaborative observations was discussed at the EISCAT Science oversight committee (SOC) meeting at Tromsoe, Norway, based on the draft.

2016-09-20: Y. Ogawa distributed the draft to ERG mailing list members and Y. Miyoshi to PIs of ERG instruments, and asked them comments and inputs on it.

2016-10-03: S. Tam commented on the draft.

2016-10-19: Y. Miyashita gave an input and comments on the draft.

2016-10-19: Y. Ogawa updated the draft based on all the comments and inputs.

2016-10-21: T. Ulich (chair of the SOC) received the latest draft, to discuss the ERG-EISCAT collaborative observations at the council meeting in UK (November 2-3).

Executive Summary

This document outlines potential collaborative observations and scientific studies involving the ERG satellite and EISCAT radars during the mission commissioning phase of the ERG in 2017 and 2018. It describes background of the missions, science targets by mission phase, and possible data usage during the coordinated ERG and EISCAT observations.

1. Introduction

The European Incoherent Scatter (EISCAT) scientific association was founded in 1975, and has conducted observations of the polar upper atmosphere over northern Scandinavia since 1981 and over Svalbard since 1996. The EISCAT radars enable us to measure ionospheric parameters (electron density, electron and ion temperatures, and ion velocity) from the D-region ionosphere (above about 60 km) to the topside ionosphere (up to about 1500 km). Combination of the EISCAT systems in northern Scandinavia and Svalbard allows extended investigations of the polar ionosphere in the polar cap, auroral zone, and sub-auroral region. Previous and present researches have been focused on solar influences of Earth's environment in conjunction with many spacecrafts (e.g., Cluster II since 2000, and SWARM since 2014). Coordinated EISCAT observations with the satellites have been conducted as Common Program (CP), special program (SP) including the third party program, and/or special programs of all EISCAT associations (AA).

One of important opportunities as next coordinated observations with satellites is collaborative magnetospheric and ionospheric researches with JAXA's Exploration of energization and Radiation in Geospace (ERG) mission (see Figure 1), which is scheduled to launch late in the Japanese Fiscal Year 2016 (April 2016-March 2017). A main science target of the ERG satellite mission is to understand the generation and loss of relativistic electrons through cross-energy and cross-regional coupling processes involving different plasma populations and regions [Miyoshi et al., 2012]. The satellite will provide in situ data of ion and electron distribution functions with wide energy range (10 eV to 20 MeV for electrons, 10 eV/q to 180 keV/q for ions with mass discriminations), electric and magnetic fields, and plasma waves in the inner magnetosphere and auroral region (Maximum dipole L-value is expected to be about 9.5). The coordinated ERG and EISCAT observations are beneficial for many scientists studying upper atmospheric and magnetospheric physics and will be widely used to understand various geophysical and plasma-physical phenomena occurring between ionosphere and magnetosphere.

The joint missions with the ERG satellite and EISCAT radars will take place for about two years after the launch of ERG satellite. Here we address outline of scientific targets for the coordinated ERG and EISCAT observations, and also possible data usage of the coordinated observations.

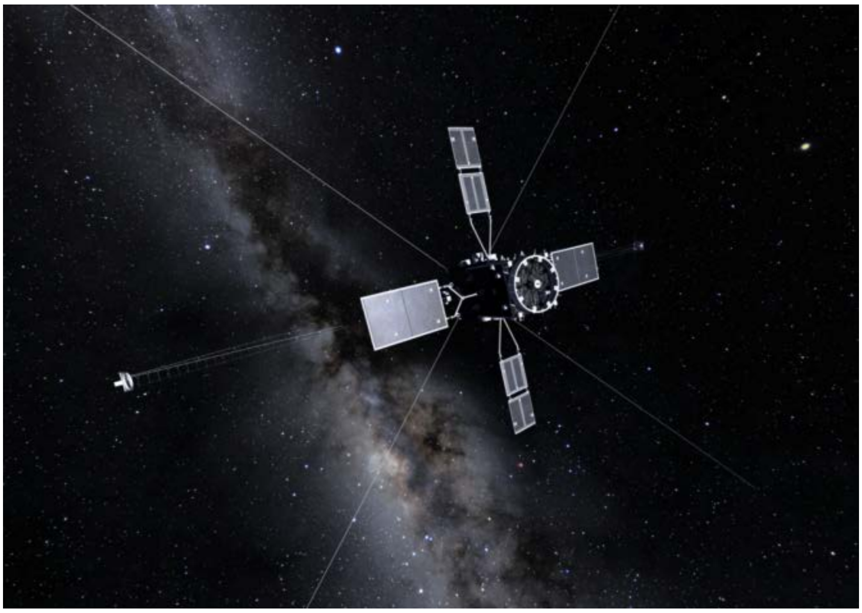

Figure 1: Schematic illustration of the ERG satellite (M-class mission of ISAS/JAXA)

2. ERG satellite orbits and instruments

The ERG satellite will have an orbit with apogee geocentric distance of 6.2 R_E, perigee altitude of 300 km, inclination angle of 31°, and orbital period of about 9 hours. Initial apogee local time of the ERG is 09 LT. The L-shell of the apogee altitude depends on season, and the expected Maximum dipole L-value is about 9.5, where the EISCAT mainland radars are located. Figure 2 shows an example of footprint of the ERG satellite over Scandinavia. When footprint of the ERG approaches the EISCAT radar site, the ERG is able to measure continuously magnetospheric plasma , and fields and waves for about 4-6 hours within the field of view of several ground observations.. Figure 3 shows time variations of conjunctions near Tromsø (Geographic latitude of 69.6 deg, Geographic longitude of 19.2 deg). The footprints of the ERG at apogee will come to the EISCAT location every season. Coordinated observations will be realized in the morning sector (00-05 MLT) about three months after the launch, in the evening sector (15-20 MLT) ten –eleven months after the launch, and in the nightside (20-02 MLT) five – seven months after the launch and also ten-eleven months after the launch.

The International Geomagnetic Reference Field (IGRF-12) will be used to calculate the magnetic footprints of the ERG observations. However, it may not be easy to find one-to-one correspondence between the ERG and EISCAT, because the field line tracing depends on the magnetic field model. We think that meso/large scale phenomena such as diffuse/pulsating aurora would be good subjects for comparison between ERG and EISCAT data, because we may observe wide-spread aurora phenomena within FOV.

The instrumentation for the ERG mission is summarized in Figures 4 and 5. The ERG measures electrons with wide energy range (from 17 eV to 20 MeV), ions with mass discriminations (H^+, He^+, He^{++}, O^+. etc) from 10 eV/q to 180 keV/q, and electric and magnetic fields with wide frequency range. The ERG has burst mode capabilities of field experiments to identify the wave form. The ERG has burst mode capabilities of fields experiments. More information on the experiments on ERG can be found in Miyoshi et al. [2012].

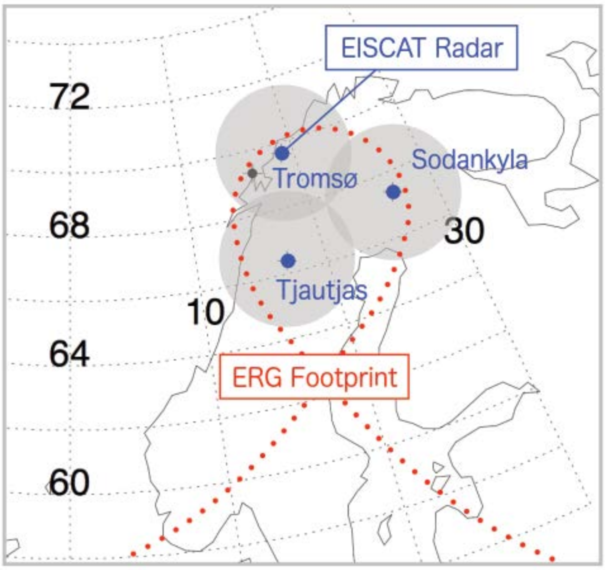

Figure 2: A predicted footprint of the ERG satellite over Scandinavia. A dotted line indicates the ERG footprint. Field-of-view of all-sky cameras at Tromsø, Sodankyla, and Tjautjas is superimposed.

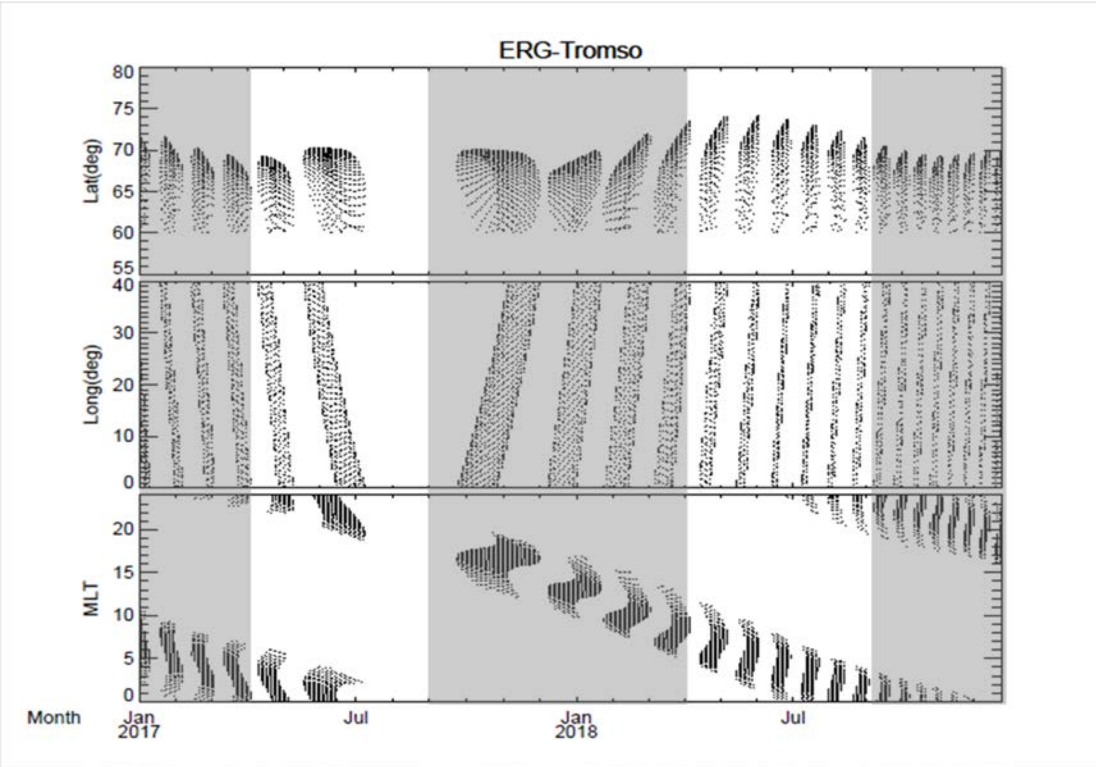

Figure 3: Time variations of predicted footprints of the ERG near Tromsø, Norway.

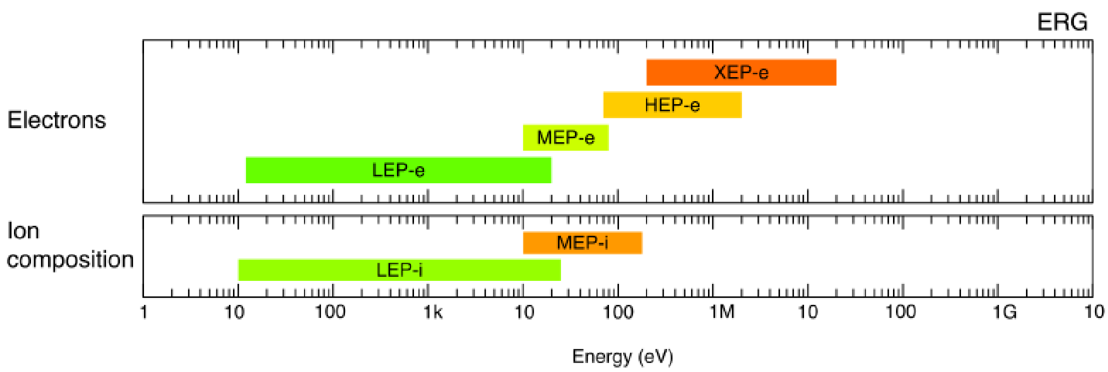

Figure 4: Particle measurements of the ERG satellite. The ERG measures ions with mass discriminations (H^+, He^+, He^{++}, O^+. etc)

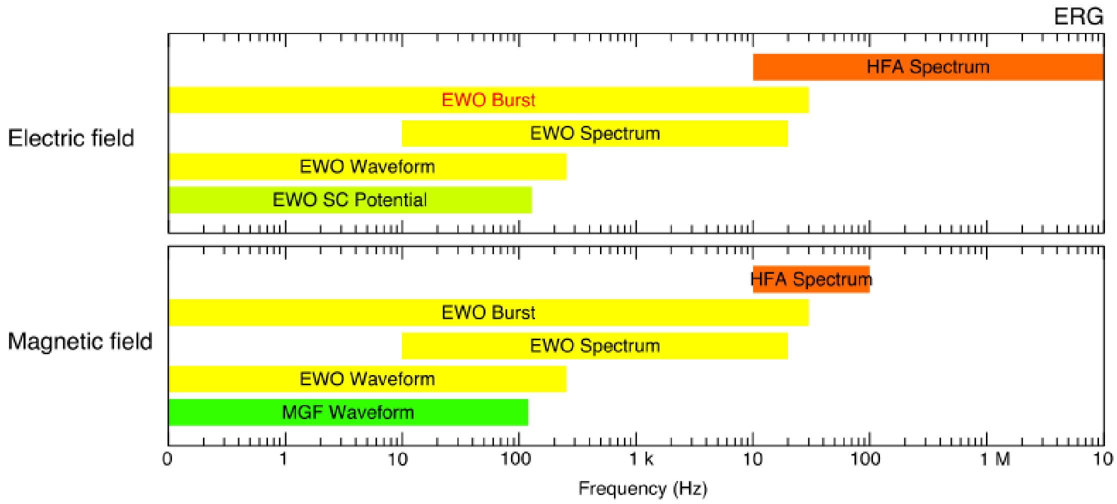

Figure 5: Electric and magnetic field measurements of the ERG satellite. Data from burst measurements are labeled in red.

3. Science targets by mission phase

We prioritize science objectives of the two-year joint observations with the ERG satellite and EISCAT radars according to the location of the spacecraft. The observation period is divided into three phases. Science targets for joint observation are identified for each phase. Figure 6 shows the location of various wave modes in the inner magnetosphere and plasma sheet. These wave modes are regarded as the primary processes for controlling the flux of energetic electrons in the outer zone radiation belt. As well as the ERG and EISCAT coordinated observations, several joint studies with ERG satellite have been planned (e.g., ERG and Van Allen Probes by Takahashi et al. [2014]; ERG and SuperDARN by Hori et al. [2016]), and thus collaborations with other satellites and ground-based projects are also important for comprehensive understanding of coupling system of the magnetosphere and ionosphere.

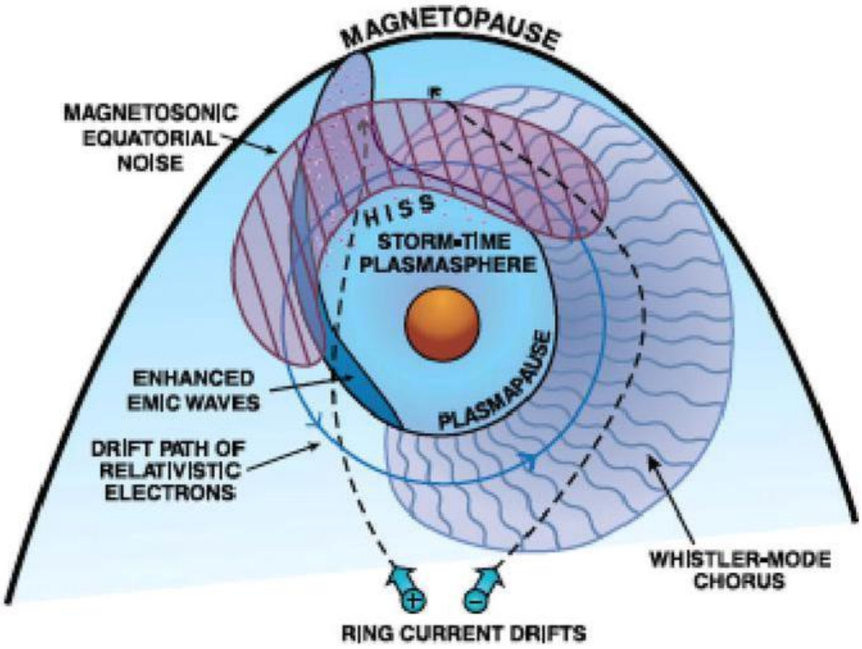

Figure 6: Schematic illustration of wave modes in the inner magnetosphere and plasma sheet and major processes in the outer zone radiation belt [Thorne, 2010].

3.1 Phase 1: Morning sector (00-05 MLT)

After commissioning operation of the ERG satellite, the normal mission by all scientific instruments will start three months after the satellite launch. The spacecraft will be ideally located for studying characteristics and generation mechanisms of chorus waves and pulsating aurora in the morning sector. Figure 7 shows ERG orbits during the phase 1. The ERG measures internally generated dawnside chorus waves and resultant pitch angle scattering of energetic electrons., whereas EISCAT radars simultaneously observe electron density modulations due to pulsating aurora and estimate precipitating electron energy spectrum and fluxes. From the previous observations, wide energy electron precipitations from keV to a few hundred keV are expected associated with the pulsating aurora [Miyoshi et al.,, 2015]. During the ERG-EISCAT observations, burst mode observations of the ERG wave instruments and fine channel observations of a few keV electrons will be used for identification of chorus wave modulation and its relation to pulsating aurora.

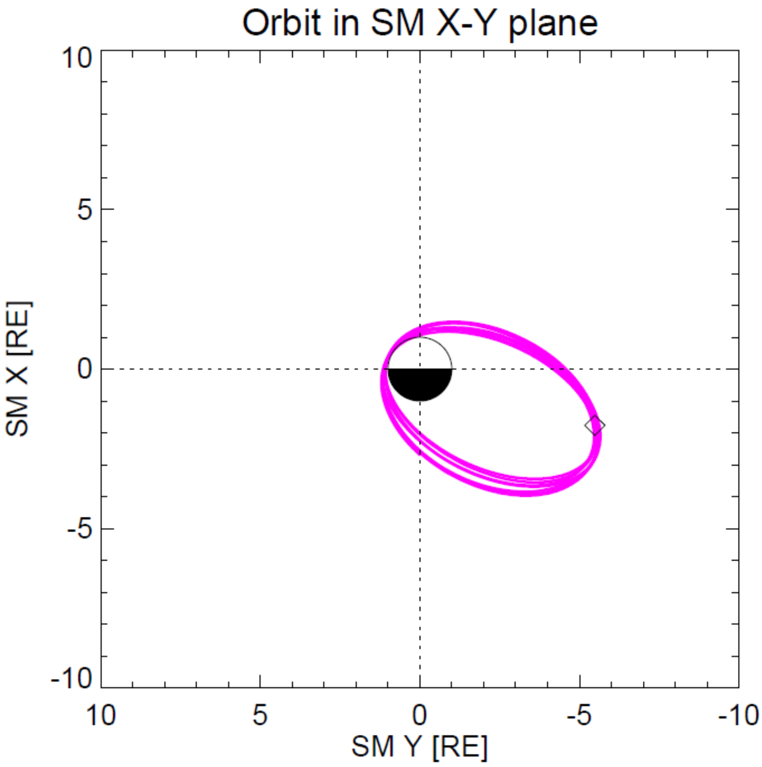

Figure 7: ERG orbits during the phase 1.

3.2 Phase 2: Nightside sector (20-02 MLT)

Magnetic storm and auroral substorms frequently occur during equinox. Significant contribution of hot O^+ ions (> keV) to inner magnetospheric plasma pressure during the magnetic storm has been discussed in the previous study. However, response of mass transfer between ionosphere and magnetosphere to solar wind variations is not fully understood. ERG will simultaneously measure cold (< 100 eV) and hot O^+ ions (> keV) in the inner magnetosphere, whereas EISCAT measures time and height variations of ionosperic O^+ upflow. Ion instruments with time resolution of 8-sec are desirable during the magnetic storm.

Energetic particle injection is important for understanding seeds for the radiation belt. Injection is caused by substorm dipolarization in the near-Earth magnetotail. Energetic particles then drift in the inner magnetosphere around the Earth and precipitate into the ionosphere and even into the upper atmosphere. The ERG satellite will observe not only dispersed drift echoes away from the particle acceleration region but also dispersionless injection in the acceleration region or in a region magnetically connected to the acceleration region. On the other hand, the EISCAT radars can monitor injection by observing energetic particle precipitation associated with injection. Combining

ERG and EISCAT observations will deepen our understanding of how and to what energy particles are accelerated.

3.3 Phase 3: Evening sector (15-20 MLT)

During a magnetic storm, EMIC waves are often excited in the evening sector near the plasmapause. However, contribution of the EMIC waves to loss of electrons in the radiation belts and its relation to proton precipitation into the ionosphere are not clear yet. In this phase 3, we investigate excitation of the EMIC waves in the dusk sectors with ERG wave and ion measurements, whereas ground-based optical instrument can simultaneously identify proton aurora at the same sectors. High-speed meridional scans of the EISCAT UHF radar is effective for investigation of the altitude profile of electron density in the sub-auroral region (see Figure 9). Burst mode of ion and wave instruments are desirable during the coordinated observations.

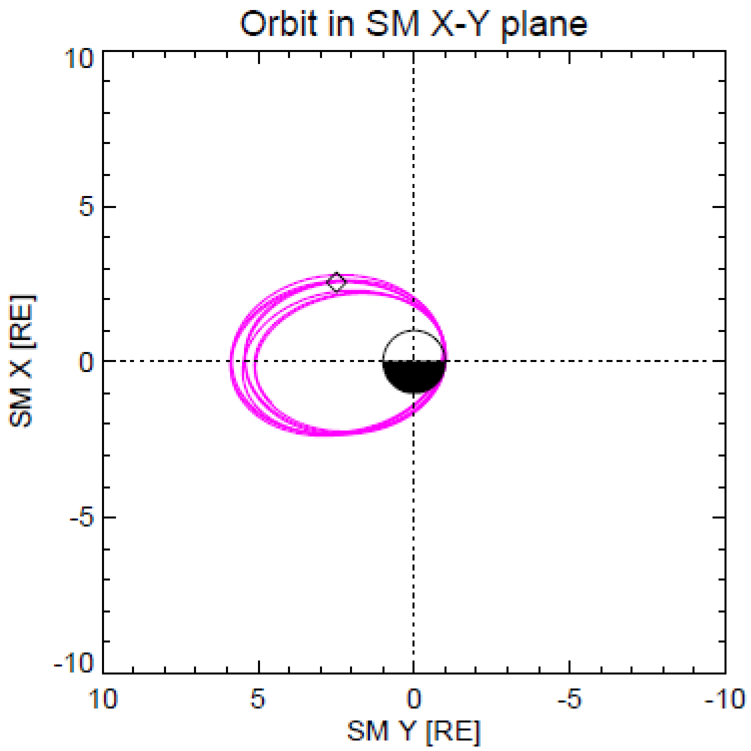

Figure 8: ERG orbits during the phase 3.

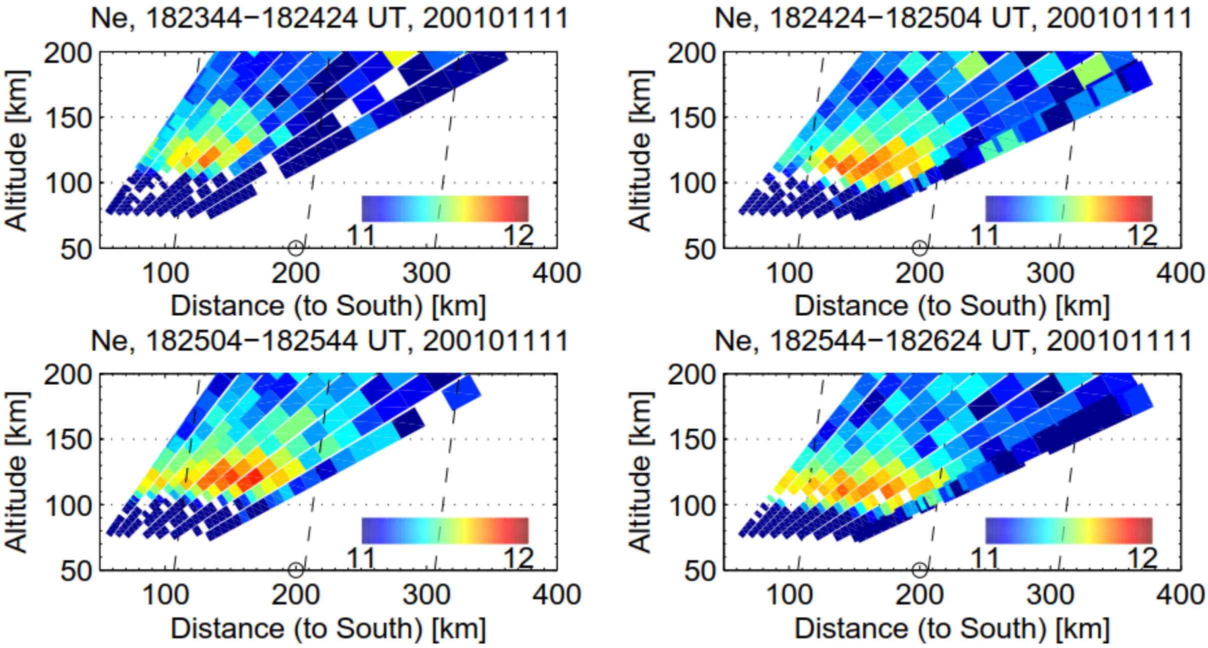

Figure 9: Examples of electron density data with the EISCAT high-speed meridional scan. Horizontal axis indicates distance from the EISCAT Tromsø UHF radar.

4 Data policy of the EISCAT, ERG, and their coordinated observations

4.1 EISCST data policy

The EISCAT data policy is summarized in page 39 of the EISCAT Bluebook Edition 2015 (https://www.eiscat.se/eiscat2014/eiscat-bluebook-edition-2015/view). Common program (CP) data are immediately distributed all over the world after their observations. Special program (SP) and Peer review program (PP) data are for exclusive use of the user who carried out the observation during 1 year, and for exclusive use within the EISCAT membership for 2 following years. SP data by all association (AA) are for exclusive use of the all users in associates and affiliates for 1 year. Rules of the road of EISCAT data are written in the following website: https://www.eiscat.se/groups/Documentation/UserGuides/EISCATRules/rules_of_the_road.html

4.2 ERG data policy

Regarding a plan of data policy for normal ERG observations, the ERG-Science data will be opened to the public via the ERG-Science Center website (http://ergsc.isee.nagoya-u.ac.jp/index.shtml.en) after necessary calibration. Necessary period for the calibration differs depending on the instruments. We estimate the calibration will take about a few months - one year at the latest. CDF data format is used for data of all instruments of ERG. Details of the ERG-Science Center are written by Hori et al. [2013, 2015]

4.3 Data policy of the coordinated ERG and EISCAT observations

A plan of data policy for ERG-EISCAT coordinated observations is currently under considerations. As a plan in the on-going discussion, EISCAT team members of the coordinated observations can basically use the ERG-Science data for the defined period for the coordinated observation studies as the same policy as the ERG project team members. In any case, contact to the ERG project and PI(s) of instruments on ERG is necessary before any presentation and publication. Redistribution of the ERG-Science data without permission of the ERG project is strictly prohibited.

EISCAT observations for collaboration with the ERG satellite will be conducted as a combination of the CP, SP, PP, and AA. All EISCAT data defined as the coordinated observations will be processed to make CDF format files, and integrated with other related data. The ERG team member can also use the EISCAT data as collaborative studies. A web tool named "Conjunction Event Finder (CEF)" [Miyashita et al., 2011] will be used to browse quick-look data from ERG satellite and EISCAT coordinated observations.

References

EISCAT Bluebook EDITION 2015 (2015), EISCAT scientific association. https://www.eiscat.se/eiscat2014/eiscat-bluebook-edition-2015/view

Miyashita et al. (2011), A powerful tool for browsing quick-look data in solar-terrestrial physics: "Conjunction Event Finder", Earth Planets Space, 63, e1–e4.

Miyoshi, Y. et al. (2012), The Energization and Radiation in Geospace (ERG) Project, in Dynamics of the Earth’s Radiation Belts and Inner Magnetosphere, Geophysical Monograph Series, 199, edited by D. Summers, I. R. Mann, D. N. Baker and M. Shultz, doi:10.1029/2012GM001304, AGU, 103–116.

Miyoshi, Y. et al.(2015), Energetic electron precipitation associated with pulsating aurora: EISCAT and Van Allen Probe observations, J. Geophys Res., 120, doi:10.1002/2014JA020690.

Hori et al. (2015), CDF data archive and integrated data analysis platform for ERG-related ground data developed by ERG Science Center (ERG-SC), J. Space Sci. Info. Jpn., vol. 4, JAXA-RR-14-009 (ISSN 1349-1113), 75-89.

Hori et al. (2015), An integrated analysis platform merging SuperDARN data within the THEMIS tool developed by ERG-Science Center (ERG-SC), Adv. Polar Sci., 24,

doi:10.3724/SP.J.1085.2013.00069, (2013), 69–77.
Hori et al. (2016), Memorandum for ERG and SuperDARN collaborative studies.
Takahashi et al. (2014), Opportunities for cooperation: Van Allen Probes and ERG.
Thorne, R. M. (2010), Radiation belt dynamics: The importance of wave-particle interactions, Geophys. Res. Lett., 37, L22107.