An idea for possible common program (CP) modes for EISCAT_3D

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14th EISCAT_3D user meeting &
2nd EISCAT_3D Software and Data meeting
November 29-30, 2021

Outline

1. Background of Common Program (CP)

2. Some of ideas for CP modes
   Derivations of ionospheric currents,
   Joule heating rates, and neutral winds
   along the magnetic field line or over a wider area

3. Proposal of CP working group

Common Program (CP) observations

Important points:

- Continuation from current EISCAT observations

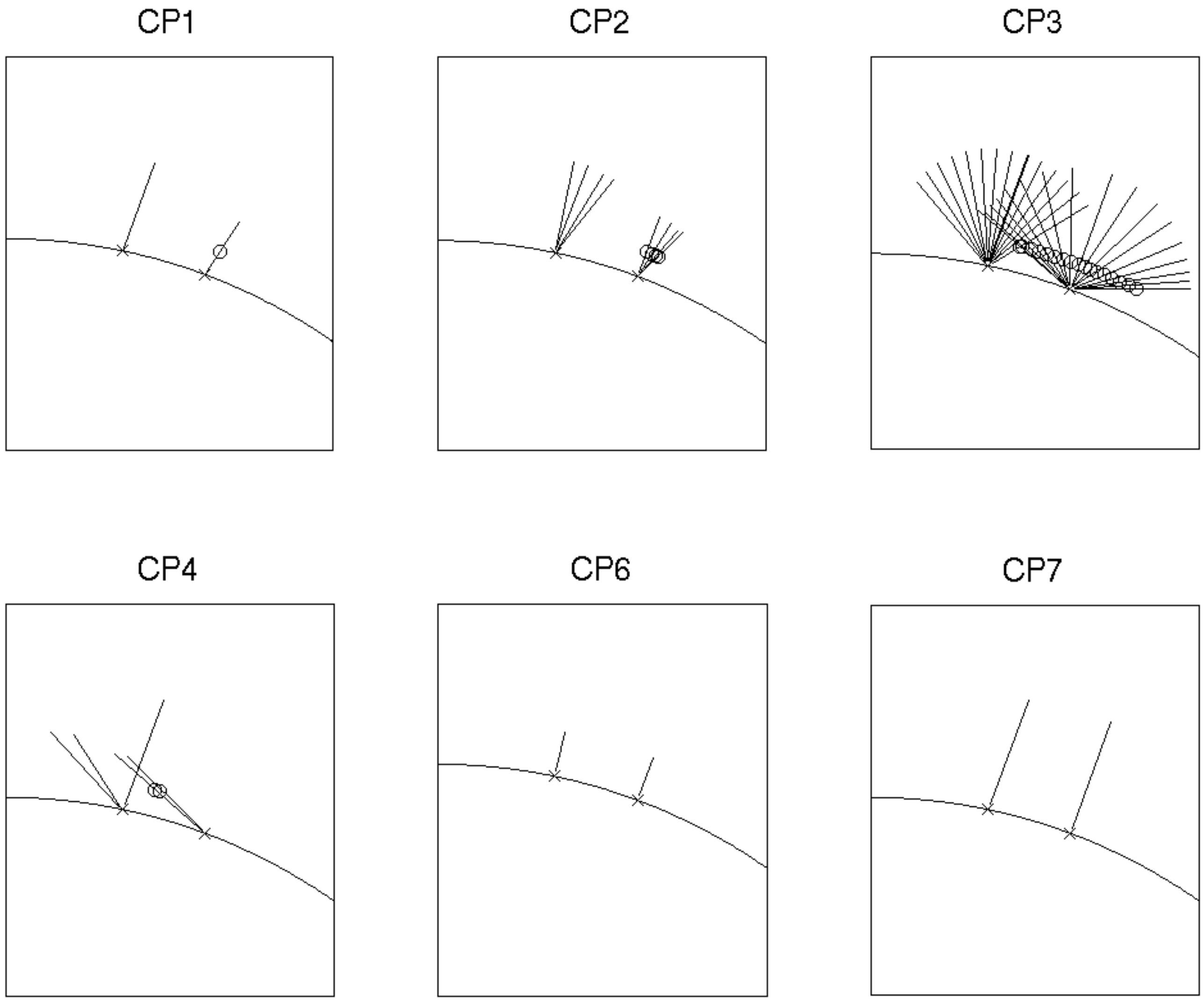
For examples, statistical analysis including long-term data analysis since 1981, and comparison study with past events.

- Joint observations with other ISR radars (ISR World days)

To provide data that can be used by researchers all over the world for various research purposes.

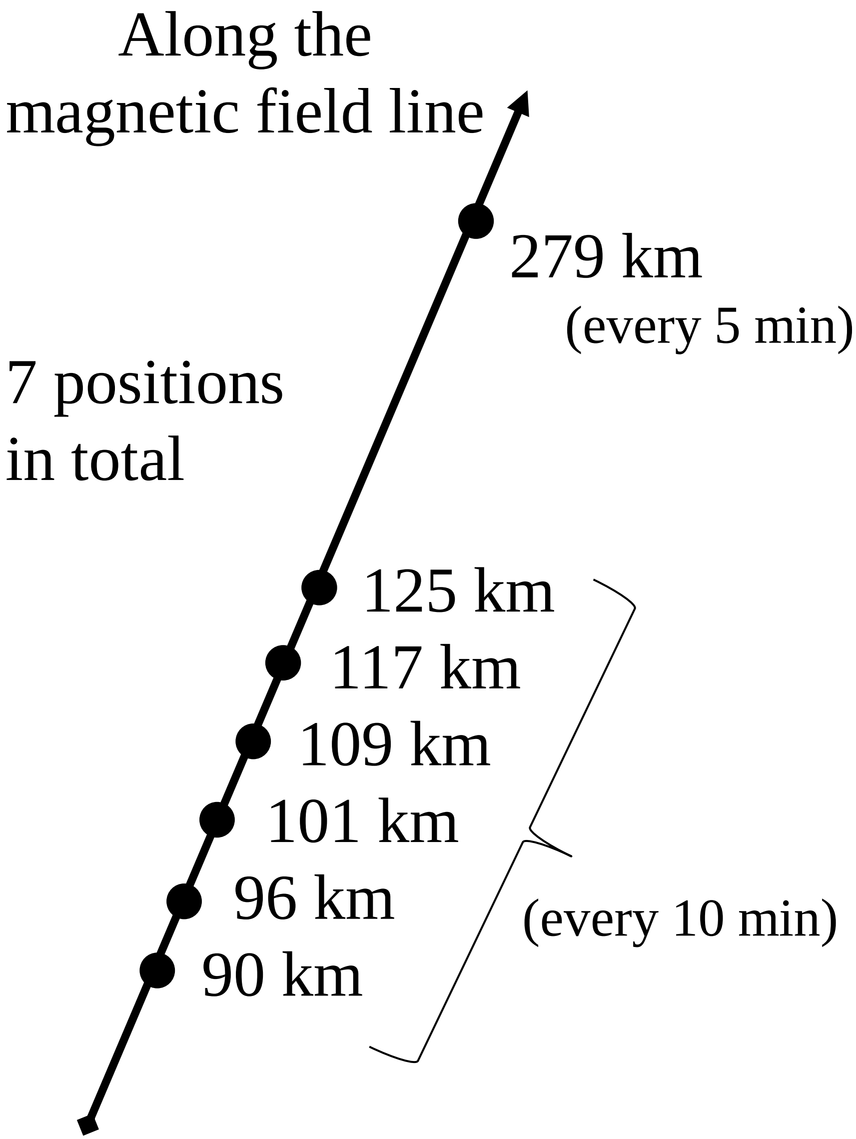
Individual unique experiments will be conducted in Special Programs (SP) and Peer-reviewed programs (PP), and so on.

Current Common Program (CP) modes



https://eiscat.se/scientist/user-documentation/radar-scan-patterns/

Previous CP-1 (CP-1-i)



	Start Time		End Time	
Year	Date	UT	Date	UT
1989	Jan. 10	0900	Jan.11	2255
1989	Feb. 7	0905	Feb. 8	0930
1989	March 28	0810	March 29	2145
1989	May 2	0800	May 3	0755
1989	Aug. 1	1300	Aug. 3	1550
1989	Sept. 5	1000	Sept. 6	1250
1989	Nov. 14	1000	Nov. 16	1600
1990	April 9	1020	April 10	1555
1990	June 5	1000	June 6	1555
1990	June 12	0800	June 13	1335
1990	July 2	1030	July 3	1550
1990	July 30	1940	Aug. 1	0355
1990	Sept. 25	1000	Sept. 27	2150
1990	Nov. 27	1000	Nov. 28	1550
1991	Feb. 20	1000	Feb. 21	1135
1991	May 2	1010	May 3	1345
1991	July 10	1430	July 11	1550
1991	Sept. 10	0900	Sept. 11	1555
1991	Dec. 8	1055	Dec. 10	1555

From Fujii et al., *JGR*, 1998

Common Program (CP) modes of AMISR

AMISR has 3 primary CP modes (IPY, World Day, and Themis mode). The temporal resolution for the AMISR data is decided post production but it is generally provided at 1 minute, 3 minute and 5 minute resolution.

Inputs from Roger Varney at the 70^{th} SAC meeting

IPY mode of PFISR

The PFISR IPY observations of ionospheric climate and weather, J.J. Sojka, M.J. Nicolls, C.J. Heinselman, J.D. Kelly, Journal of Atmospheric and Solar-Terrestrial Physics 71 (2009) 771–785.

… The normal IPY mode is a single-look direction (up the local magnetic field line: azimuth 154.31, elevation 77.51), low duty cycle mode (1%) that is designed for background characterization of the Poker Flat ionosphere. Augmented IPY modes include an additional two beams designed for characterization of the background electric field (e.g., Heinselman and Nicolls, 2008) and a full duty cycle mode operated for 24 h approximately every 2 weeks…

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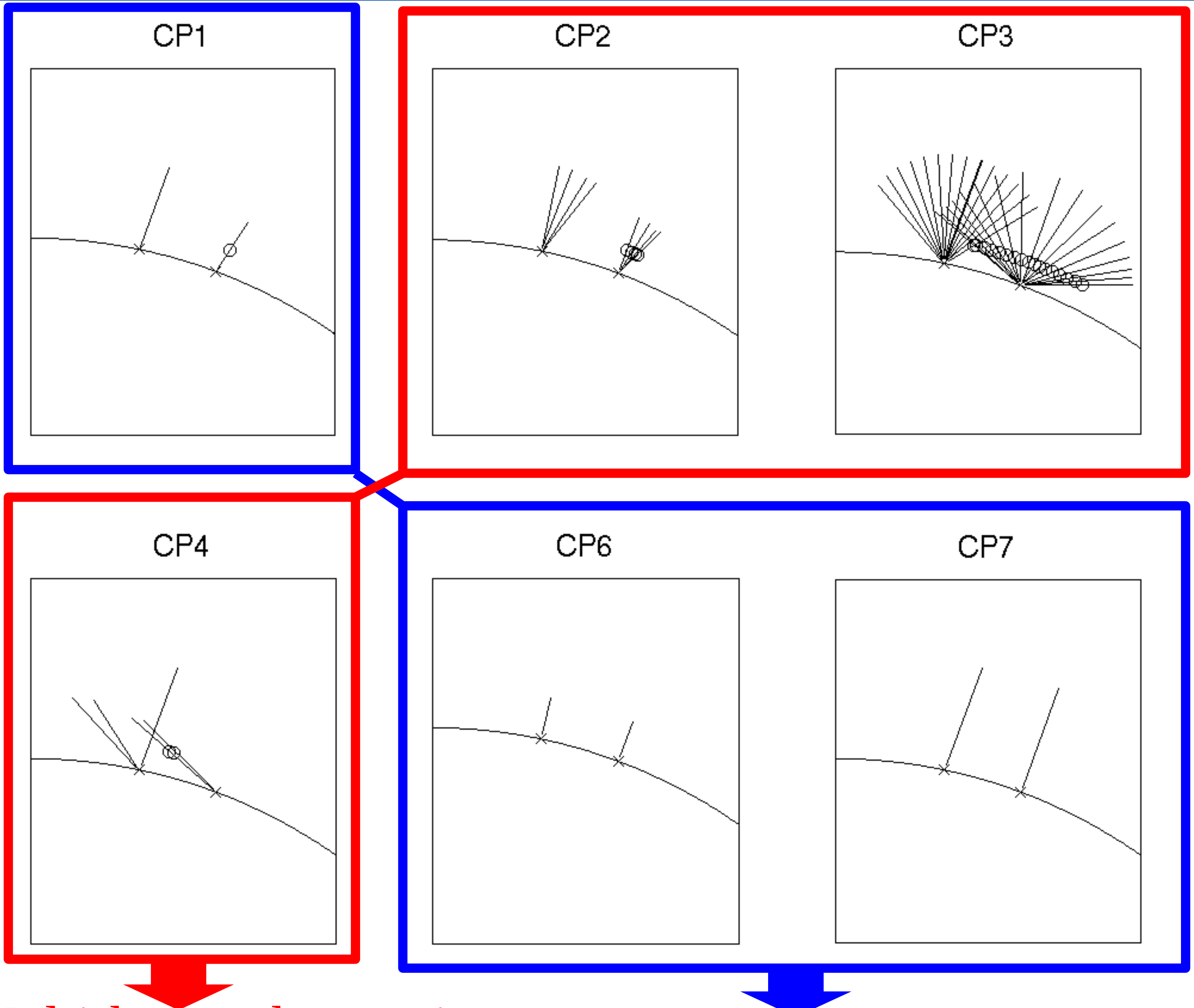
Some of ideas for CP modes

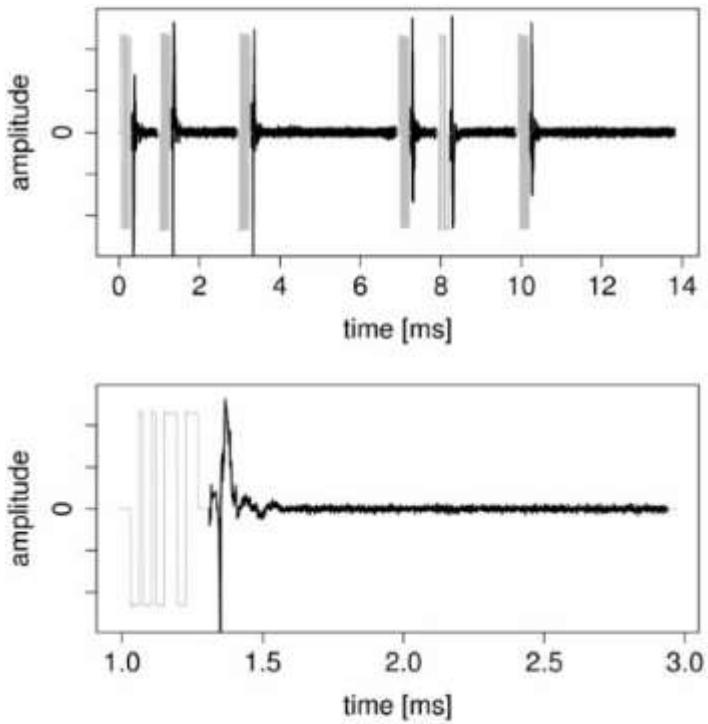


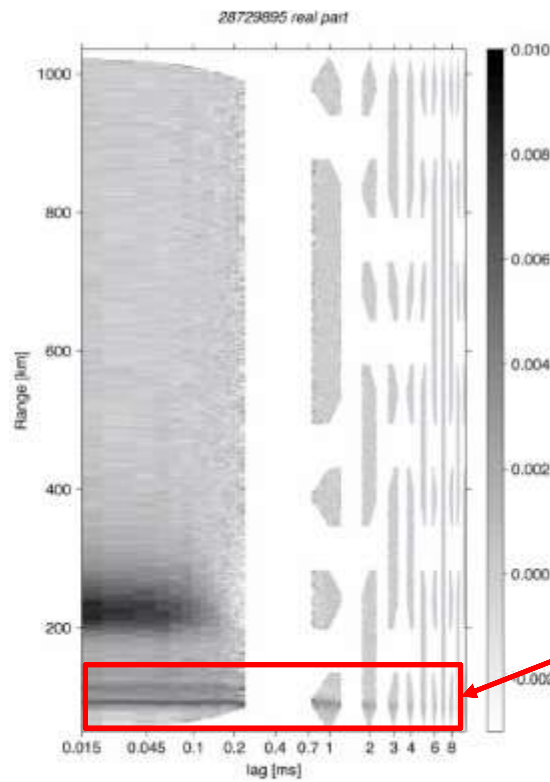
(Case 1 & 2) Multi-beam observations with multi-static measurements

(Case 0) One-beam *FA* observation with multi-static measurements

(Case 0) One-beam *FA* observation with multi-static measurements

- Multipurpose modulations using Aperiodic Transmitter Coding (ATC) will be useful.
- Range coverage: ~50 – 1000 km.
- High radar efficiencies in the *D*-, *E*-, *F*-regions and topside ionosphere (better than those of the current Alternating Codes?). Lag profile inversion is required.





Remote site data can fill the gap in the *E*- and *D*- regions

Virtanen et al., Ann. Geophys, 2009

Interleaved FA beam mode

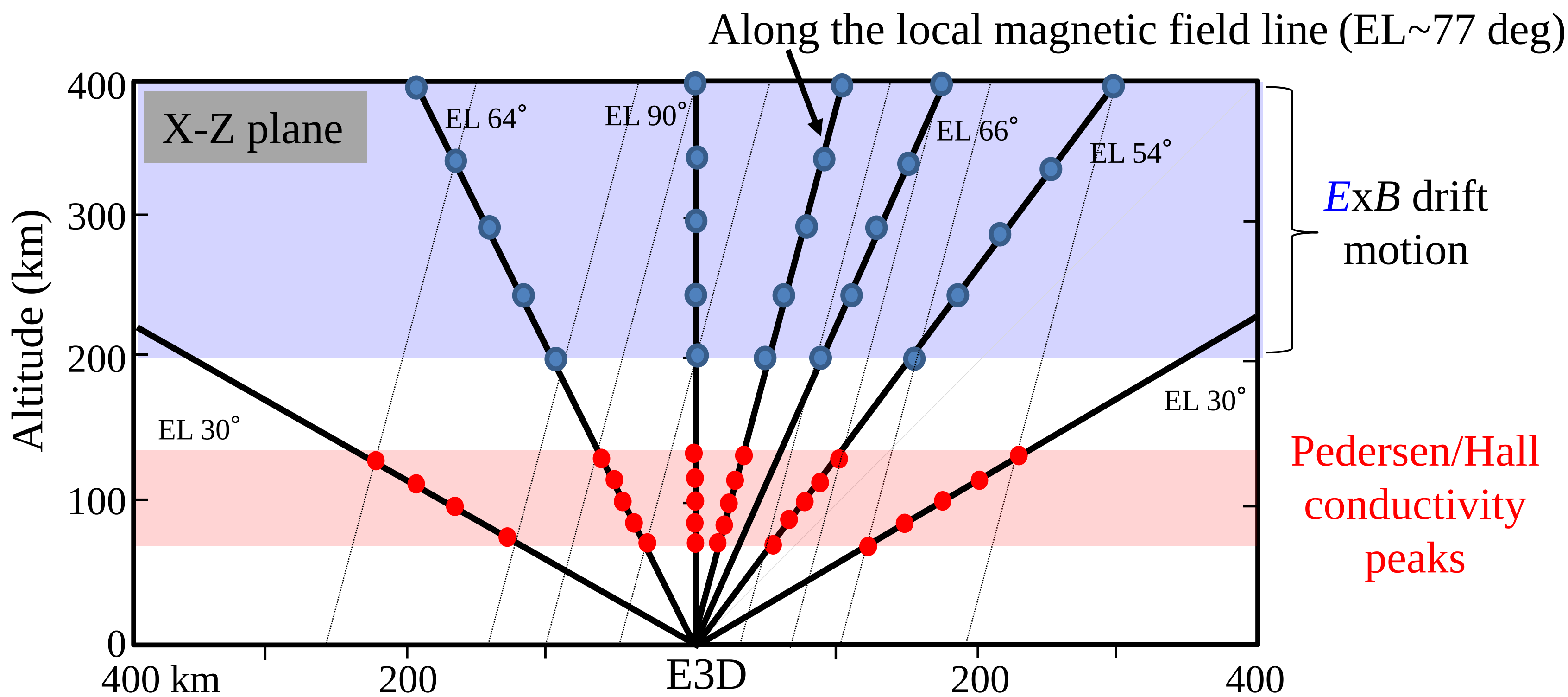
SAC highly recommends an EISCAT_3D ”camping beam” mode in a field aligned position (embedded within a multi-beam mode). Such an interleaved beam approach will be possible on EISCAT_3D.

Report from the 70th SAC meeting

Please see Ian McCrea’s presentation slide at E3D UM on May 6, 2013. Title: “Experiment Modes for various science applications in EISCAT_3D”

Multi-beam observations with EISCAT_3D

(Case1) An example of multi-beam and multi-static observations



7 beams in the North-South meridian plane (from EISCAT_3D)

Electric field data & Pedersen/Hall conductivity data → Ionospheric current data

$$\mathbf{J} = \sigma_P(\mathbf{E} + \mathbf{u}_n \times \mathbf{B}) - \sigma_H\left[(\mathbf{E} + \mathbf{u}_n \times \mathbf{B}) \times \frac{\mathbf{B}}{B}\right]$$

Multi-beam observations with EISCAT_3D

(Case1) An example of multi-beam and multi-static observations

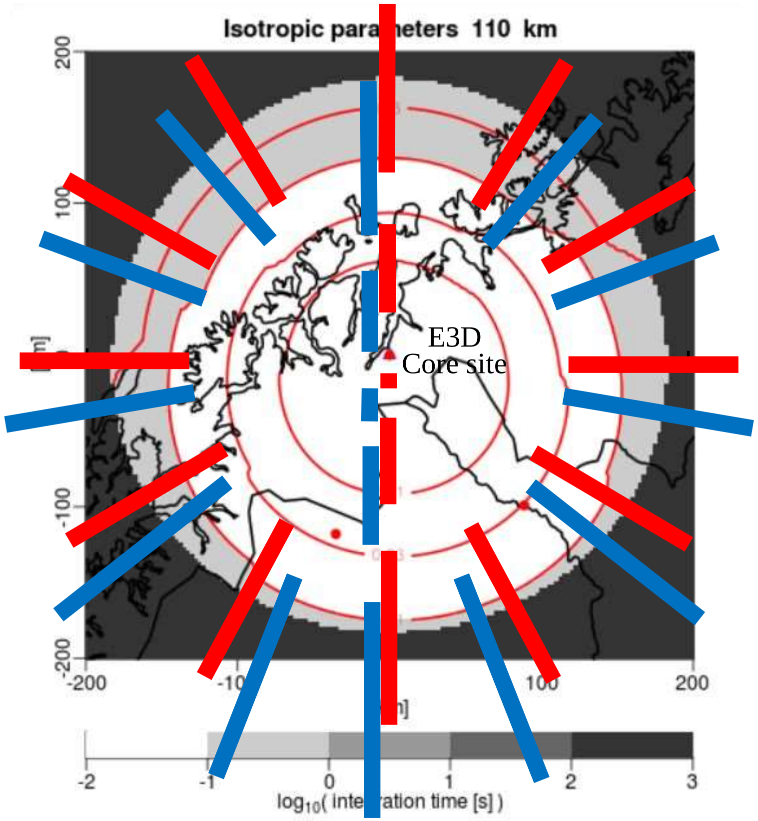
(Continued from the previous page)

7 + 10 x 2 = 27 beams in total

Minimum time resolution required: ~34-sec
(= ~0.3-s *12 beams for E-region
+ ~2-s *15 beams for F-region.
TX will be divided between the beams on pulse-to-pulse basis, so that the final time-resolution can be selected afterwards.)

(blue line)	200-400 km alt. (Beam with 55~63 deg EL)
(red line)	80-130 km alt. (Beam with 30 deg EL)

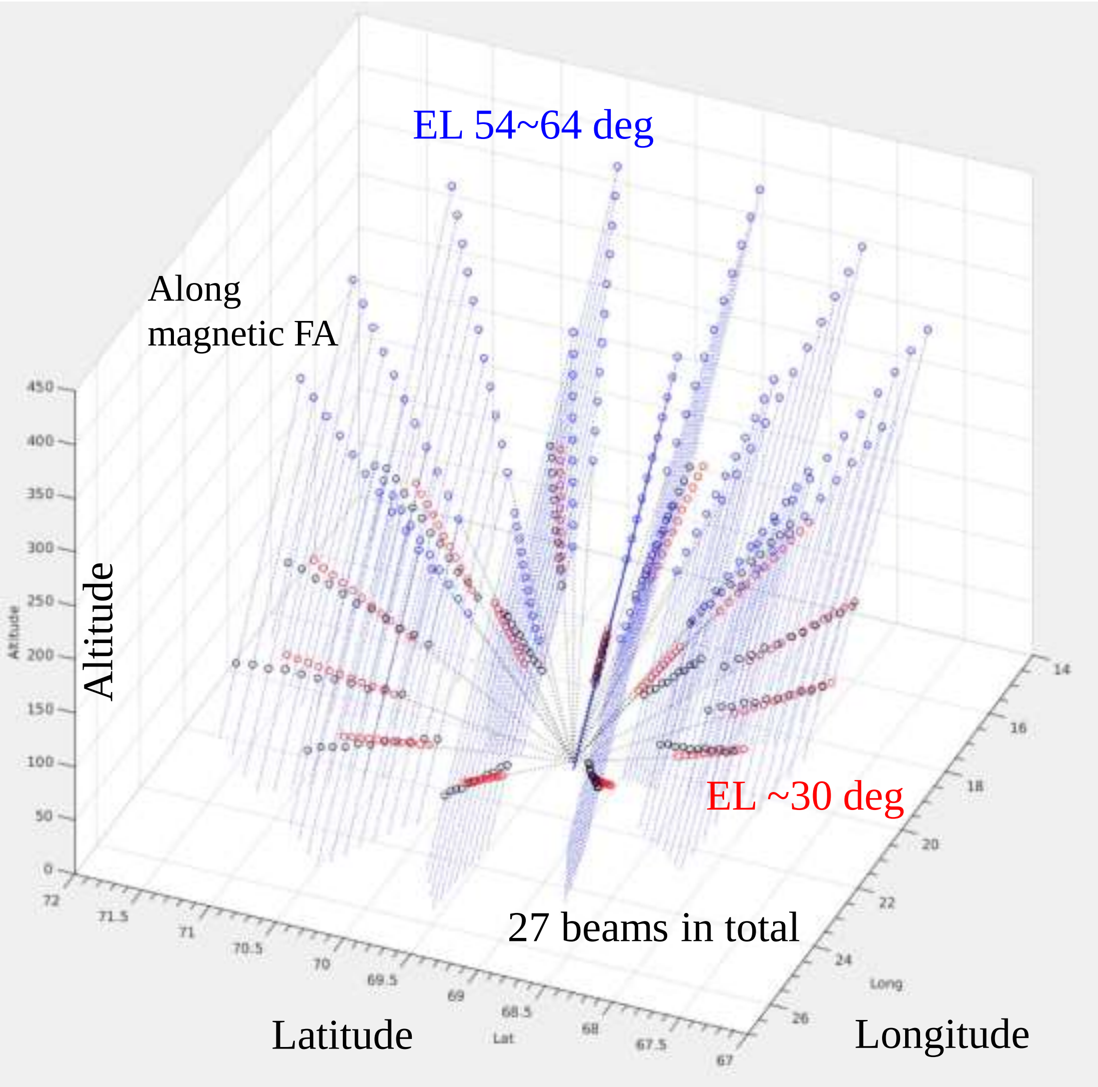
X-Y plane



Parameters changed from [Virtanen, 2011]

110 km altitude, 3 sites, 3.5MW Tx power,
5% Noise level, 2 km range resolution,
Background Ne = 2x10^{11}[m^{-3}].

Multi-beam observations with EISCAT_3D



3-D plots (the IGRF model is used)

Case 1

Beam directions of Case 1 (27 beams in total):

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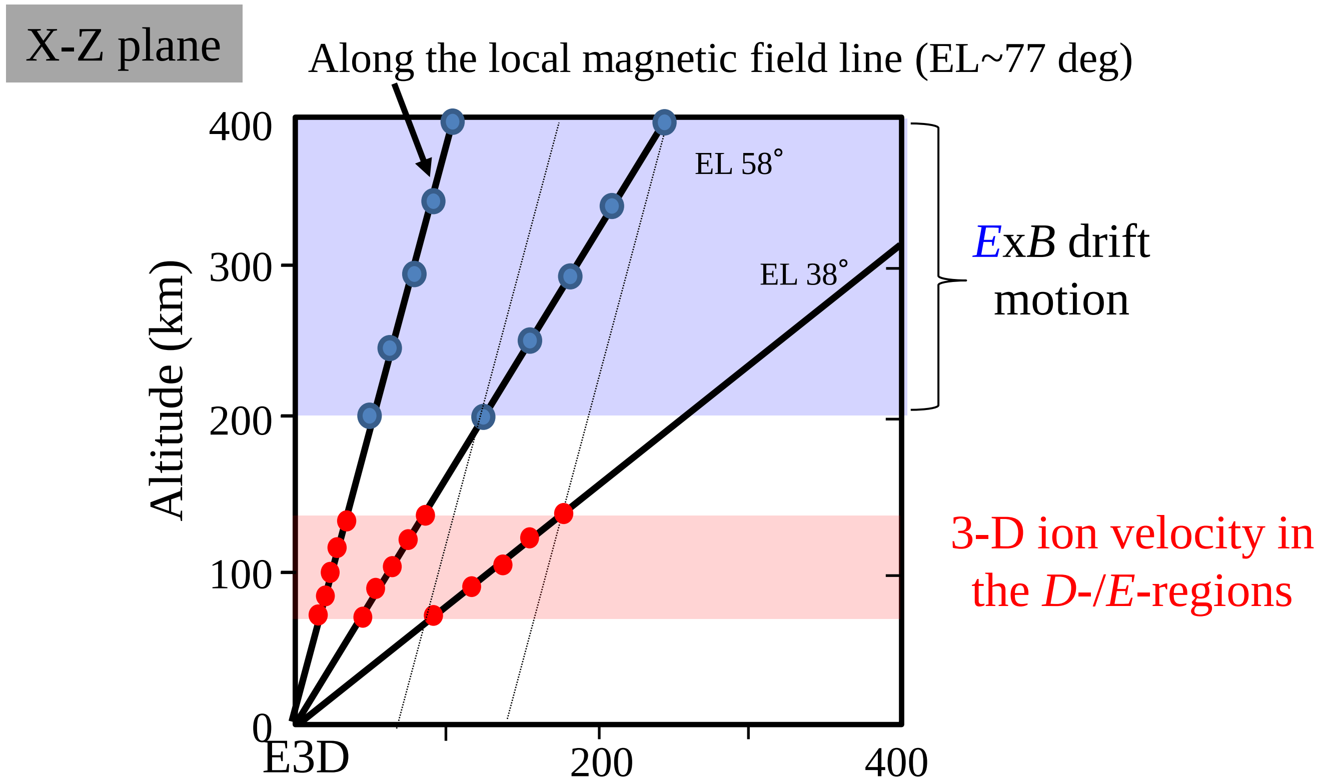
el_arr1=[64 61 60 58 57 55 54 54 57 59 61 61];
az_arr1=[0 35 69 101 130 156 180 204 231 258 288 323];

el_arr2=[30 30 30 30 30 30 30 30 30 30 30 30];
az_arr2=[0 30 60 90 120 150 180 210 240 270 300 330];

el_arr3=[66 77.8 90];
az_arr3=[180 180 180];

Multi-beam observations with EISCAT_3D

(Case 2) An example of multi-beam and multi-static observations



3 beams in the North-South meridian plane (from EISCAT_3D)

Electric field data & *D*-/*E*-region 3-D ion velocity data → Neutral wind data

$$\boldsymbol{u}_n = \underline{\boldsymbol{V}_i} - \frac{\Omega_i}{|\mathbf{B}|\nu_{in}}(\underline{\boldsymbol{E}} + \underline{\boldsymbol{V}_i} \times \mathbf{B})$$

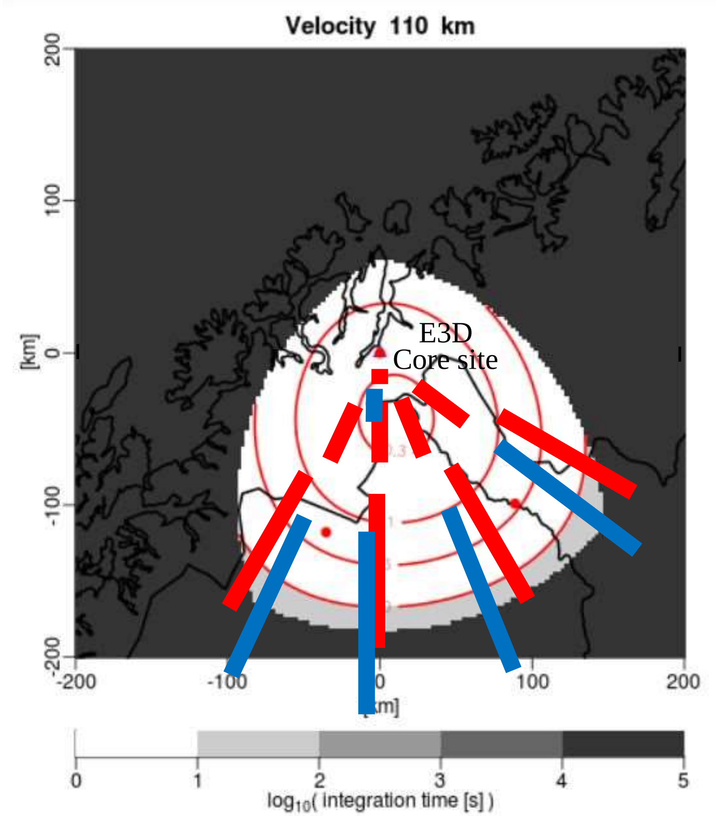
$$\boldsymbol{j} = n_e e(\underline{\boldsymbol{V_i}} - \underline{\boldsymbol{V_e}})$$

Multi-beam observations with EISCAT_3D

(Case2) An example of multi-beam and multi-static observations

(Continued from the previous page)

X-Y plane



1 + 4 x 2 = 9 beams in total

Minimum time resolution required: ~23-sec
(= ~3-s *5 beams for E-region
+ ~2-s *4 beams for F-region.)

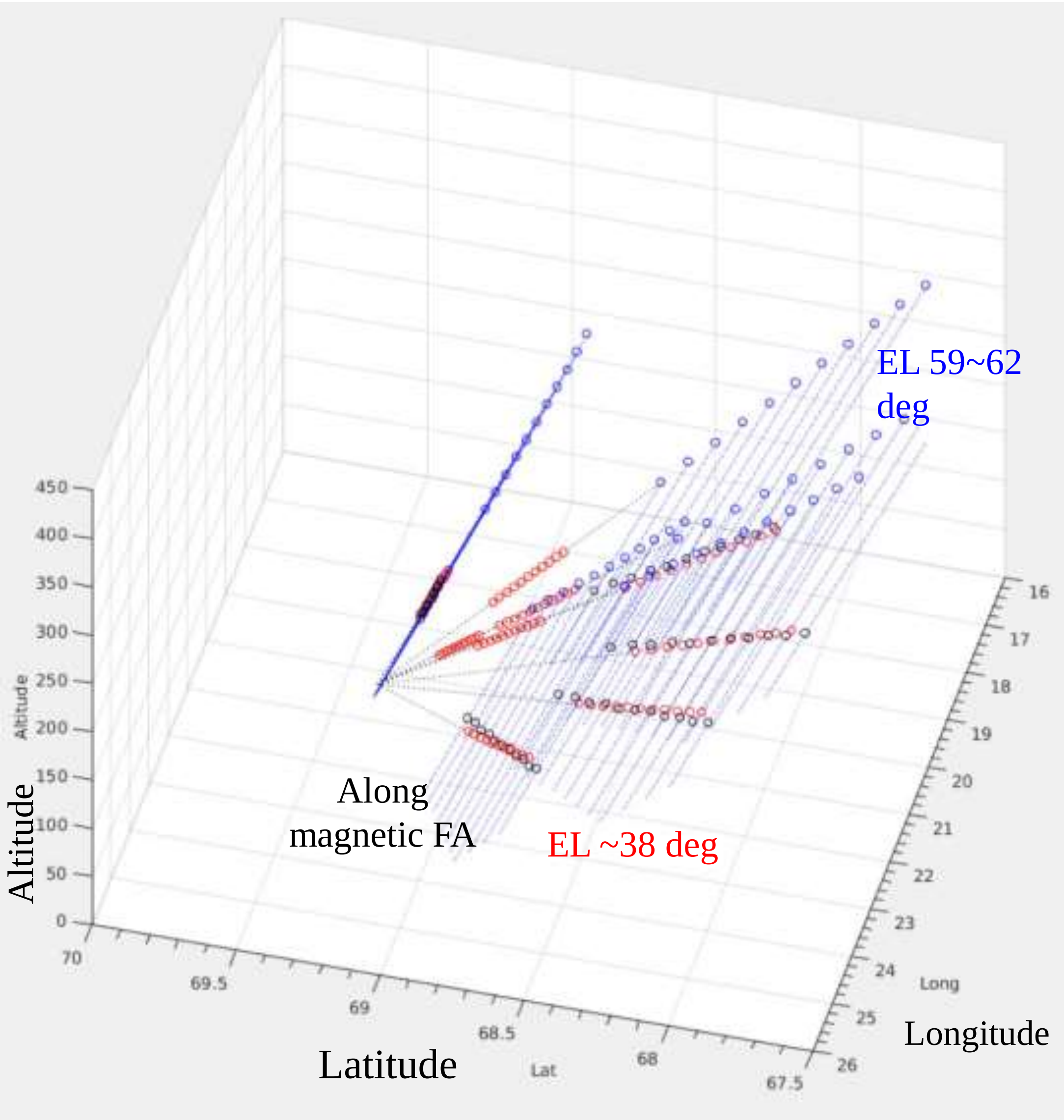
(blue line)	200-400 km alt.	(Beam with 58~60 deg EL)
(red line)	80-130 km alt.	(Beam with 38 deg EL and 58~60 deg EL)

It is also possible to derive Joule heating rate ($\boldsymbol{J} \cdot \boldsymbol{E'}$) at 9 regions.
(Note: $\boldsymbol{E'} = \boldsymbol{E} + \boldsymbol{u}_n \times \boldsymbol{B}$)

Parameters changed from [Virtanen, 2011]

110 km altitude, 3 sites, 3.5MW Tx power, 5% Noise level, 2 km range resolution, *Background Ne* = 2×10^{11} [m^{-3}].

Multi-beam observations with EISCAT_3D



3-D plots (the IGRF model is used)

9 beams in total

Case 2

Beam directions of Case 2 (9 beams in total):

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el_arr1=[62 60 59 60];
az_arr1=[135 158 182 205];

el_arr2=[38 38 38 38];
az_arr2=[120 150 180 210];

el_arr3=[77.8];
az_arr3=[180];

Action Items

- We need to consider the case of low power mode (e.g., a smaller number of beams for multi-beam observations).
- We need to check whether proposals of CP modes cover most of research targets of EISCAT_3D.
- We also need feasibility study of CP modes based on EISCAT_3D specifications
- Iterations and discussions with the EISCAT_3D user community and software working group are also important.

Proposal of CP working group

Tasks: Prepare a proposal for common program modes for EISCAT_3D radar system. Based on the proposal, discuss and revise it with the user community and EISCAT SWG members, and so on.

Members: Volunteers will be recruited.
(Their candidates:) Staff of EISCT HQ, SWG members, SAC members, Current EISCAT CP users, experts of other ISR observations,…

Table 1 EISCAT_3D resolution and range extent requirements for the different science topics. A phased array system with fast pointing, multiple beams and calibrated signal is assumed

Science topic	Parameter for which resolution is given	Temporal resolution (s)	Horizontal resolution (km)	Vertical resolution (km)	Height range (km)
Mesoscale electrodynamics and flows (including BBFs)	N_e, T_e, T_i, V_i	10	20 in the F region	2	85–400
Small-scale (auroral) dynamics	N_e	1	1	0.5	70–500
	T_e, T_i, V_i	– "–	– "–	– "–	85–400
Fine-scale auroral structures	N_e, T_e, T_i	0.1	0.1	0.2	70–200
	V_i	0.1	0.1	5	120–400
Ion outflow (natural and heater-induced)	N_e, T_e, T_i, V_i, ion comp.	10	10	20	200–1500
NEIALs (aperture synthesis imaging)	Raw data	0.03	0.05 at 300 km	1	100–1500
Ionospheric irregularities	N_e, T_e, T_i, V_i	1	1	1	90–800
Topside composition (O^+, He^+, H^+)	mi (and N_e, T_e, T_i, V_i)	10	N/A	N/A	300–1500
Transition region composition (NO^+/O_2^+ vs. O^+)	mi (and N_e, T_e, T_i, V_i)	10	N/A	10 km	100–300
High-energy particle events (SEPs, etc.)	N_e	1	10	1	50–400
	T_e, T_i, V_i	– "–	– "–	– "–	100–400
Atmosphere-ionosphere coupling (AGW, winds)	N_e, T_e, T_i, V_i, V_n	<1 min	1	0.1 or better	As low as possible—120 km
Mesosphere-stratosphere-troposphere (MST) small-scale dynamics	Vector neutral wind, N_e	<1 min	1	0.1 or better	As low as possible—110 km
D region phenomena	N_e, T_e (=T_i) V_i (=V_n)	1	1	0.3	70–90
PMSE, PMWE	Raw data, Doppler velocity, spectral width	<1 min	1	0.1 or better	55–95
Meteoroids and their effects on the background (Es, PMSE etc.), high-power mode	Raw data, polarisation matrix, and N_e, T_e, T_i, V_i	1 ms	0.01	0.01	(30) 70–200 (1000)
Planets and asteroids	Raw data, power, polarisation matrix	10-MHz sampling		15 m	
Interplanetary scintillation	Raw data	0.01	N/A	N/A	N/A
Heating experiments	N_e, T_e, T_i, V_i	1	1	1	100–2000
Heating experiments, aperture synthesis imaging	Spectra (raw data)	IPP (~2 ms)	0.01–0.05	0.1	100–300
Space debris monitoring and satellite tracking	Raw data, power, Doppler velocity	10-MHz sampling		15 m	
Meteoroid monitoring (piggyback and low-power mode)	Raw data, polarisation matrix, and N_e, T_e, T_i, V_i	IPP ~100 ms for low-power mode	0.01	Down to 10 m	(30) 70–200 (1000)

From the EISCAT_3D Science Case (PEPS, 2015)