UiT The Arctic University of Norway

EISCAT & EISCAT 3D Primer

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Source: eiscat.se

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ABOUT ME

- Bachelor of Science in **Physics** @ Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland.

- Trip to Svalbard: ❤ **Space Physics**

…

- PhD @ The University of Oslo (UiO), Oslo Norway. Sounding rocket data analysis

…

- Ass. Prof. (tenure track) @ UiT The Arctic University of Norway, Tromsø, Norway: EISCAT 3D

Picture courtesy of Jonathan Spicher

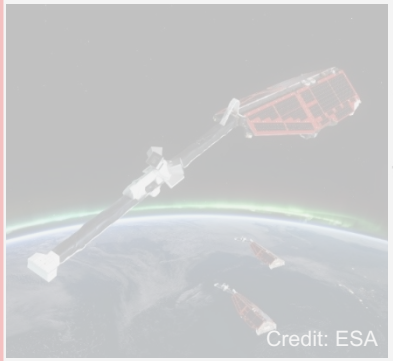
Picture credit: Njål Gulbrandsen

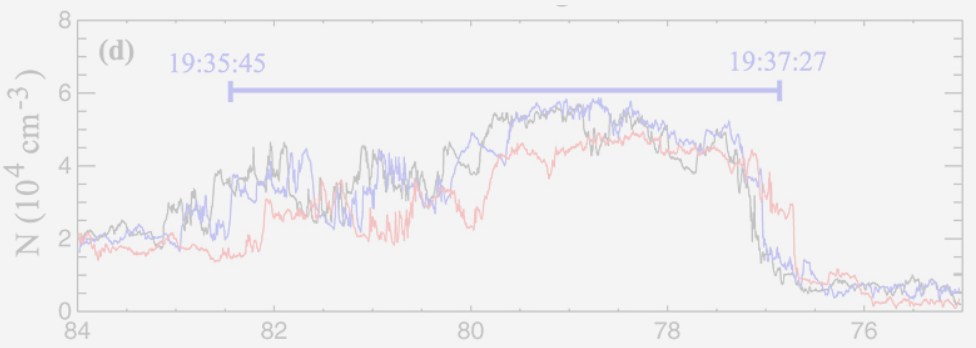
HIGHLY DYNAMIC MULTI-SCALE POLAR IONOSPHERE

THEMIS All-Sky Imager Array. Credits: NASA/Goddard Space Flight Center Scientific Visualization Studio.

INVESTIGATING THE NEAR-EARTH SPACE ENVIRONMENT

In-situ

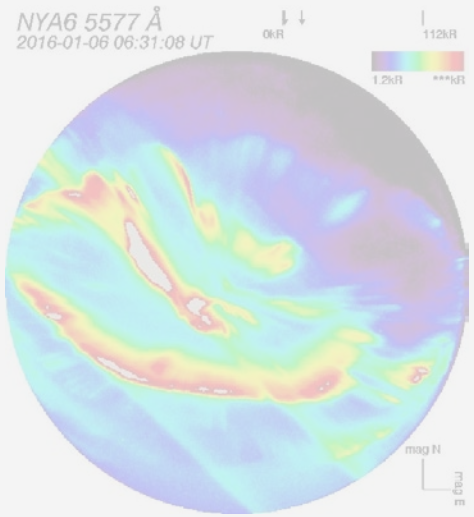




Spicher at al. (2015), Geophys. Res. Lett., DOI:10.1002/2014GL062590.14

(and more…)

Optics



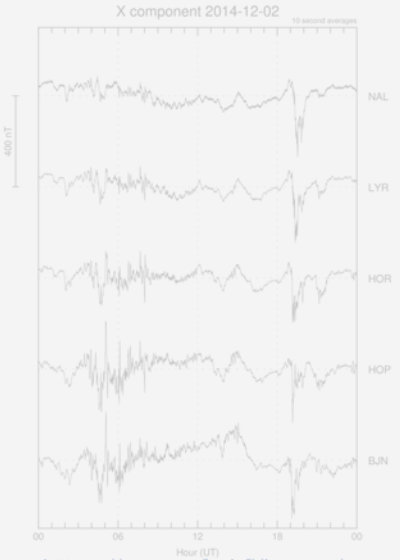
http://tid.uio.no/plasma/aurora/

Radars

Incoherent Scatter Radars

Coherent Scatter Radars

Magnetometers



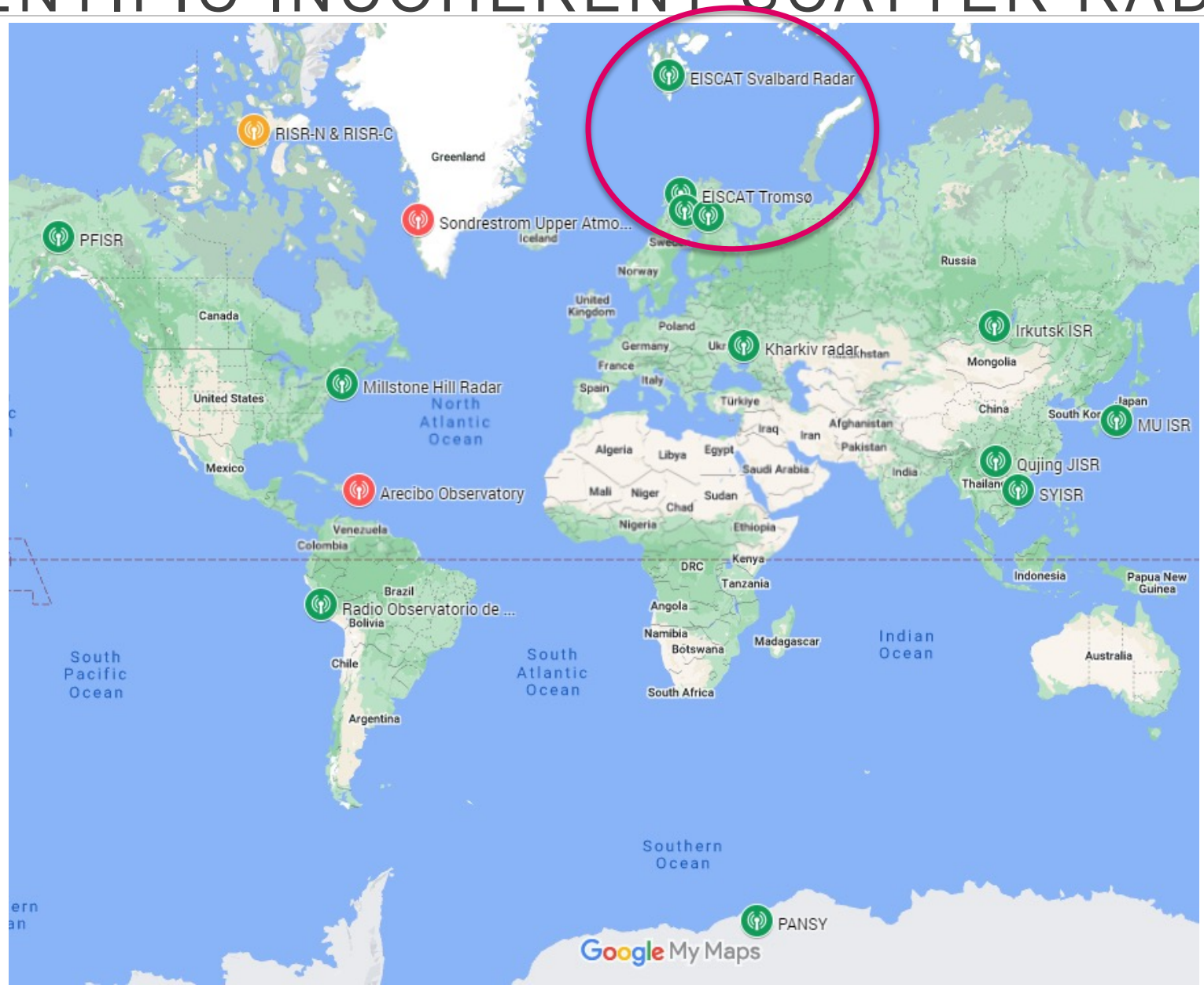
https://space.fmi.fi/image/

Credit: Njål Gulbrandsen

Credit: Njål Gulbrandsen

Credit: Njål Gulbrandsen

SCIENTIFIC INCOHERENT SCATTER RADARS



INTERNATIONAL EISCAT SCIENTIFIC ASSOCIATION

- Established in 1975.
- Non-profit scientific organization.
- Research about the upper atmosphere and ionosphere at high latitudes.
- Associate members: China, Finland, Japan, Norway, Sweden, and the United Kingdom.
- Four sites:

Norway
Svalbard: 42m & 32m dishes UHF (500 MHz)
Tromsø: VHF (224 MHz) & UHF (930 MHz) + heating facility

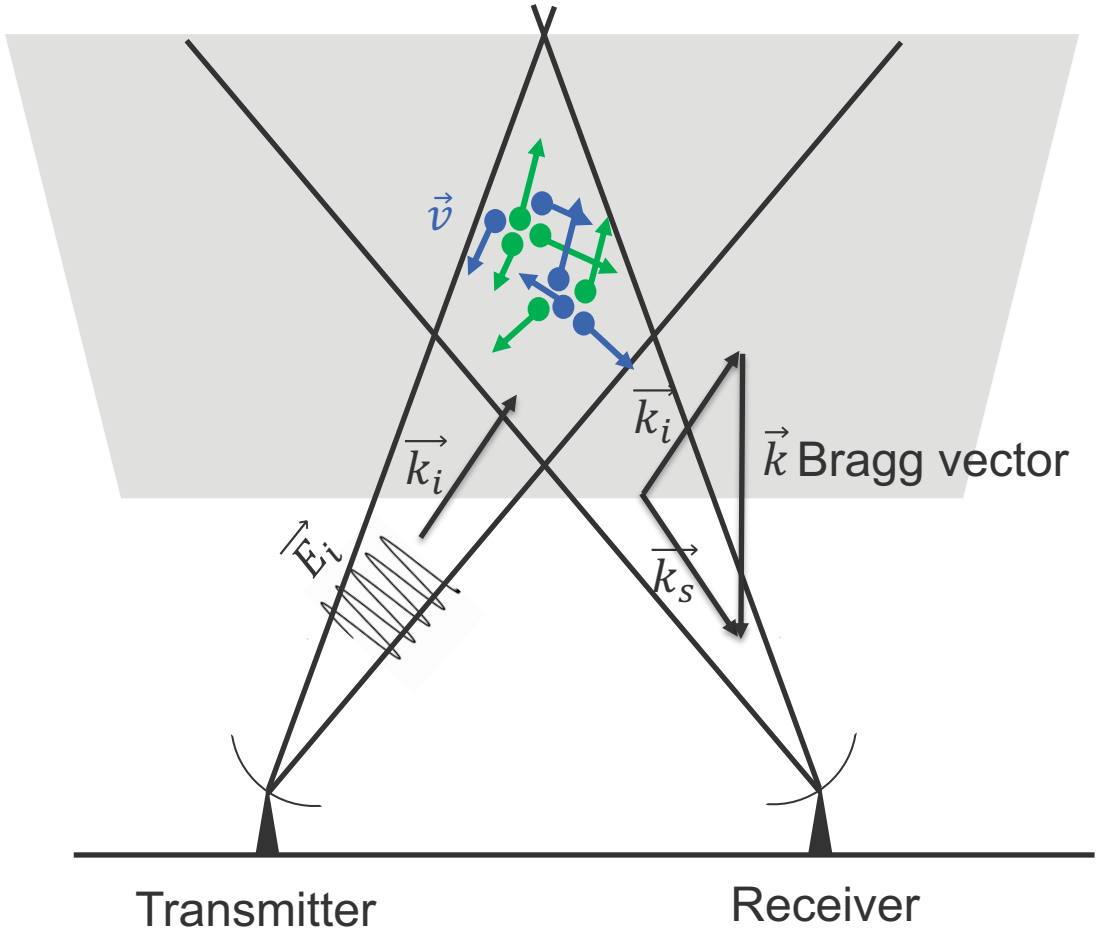
Sweden
Kiruna VHF (224 MHz)

Finland
Sodankylä VHF (224 MHz)

Credit: EISCAT (anual report 2019-2020)

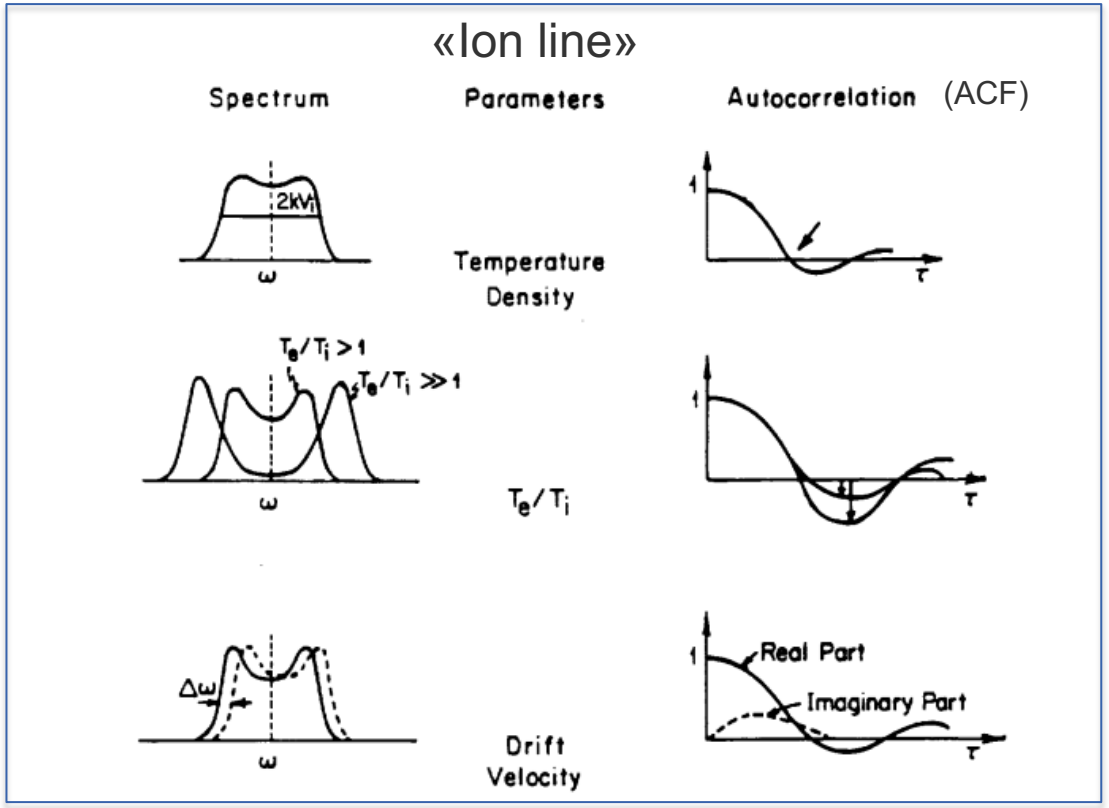
INCOHERENT SCATTERING

Thomson scattering: accelerated e^- radiate E-field.



Spectrum or ACF of received E-field related to **plasma density fluctuations** from **thermal motion and collective behavior**:

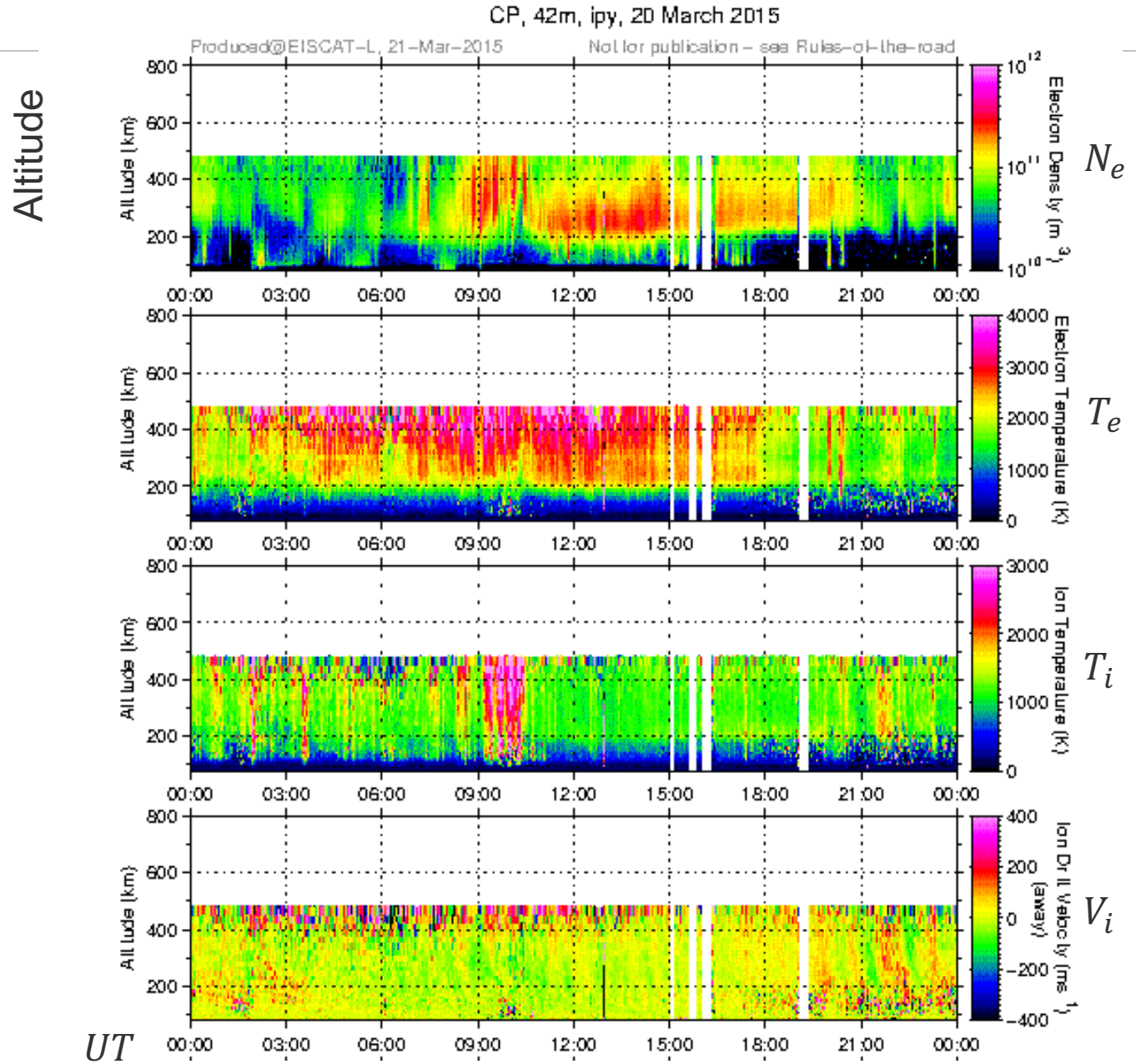
→ «Peaks» in spectrum due to ion accoustic waves & Langmuir waves.



Hagfors, T. (1989). Incoherent Scatter Radar Observations of the Ionosphere. In S. Fukao (Ed.), Middle atmosphere program. handbook for map. volume 30.

→ Electron density N_e, Electron Temperature T_e, Ion Temperature T_i, Ion velocity V_i

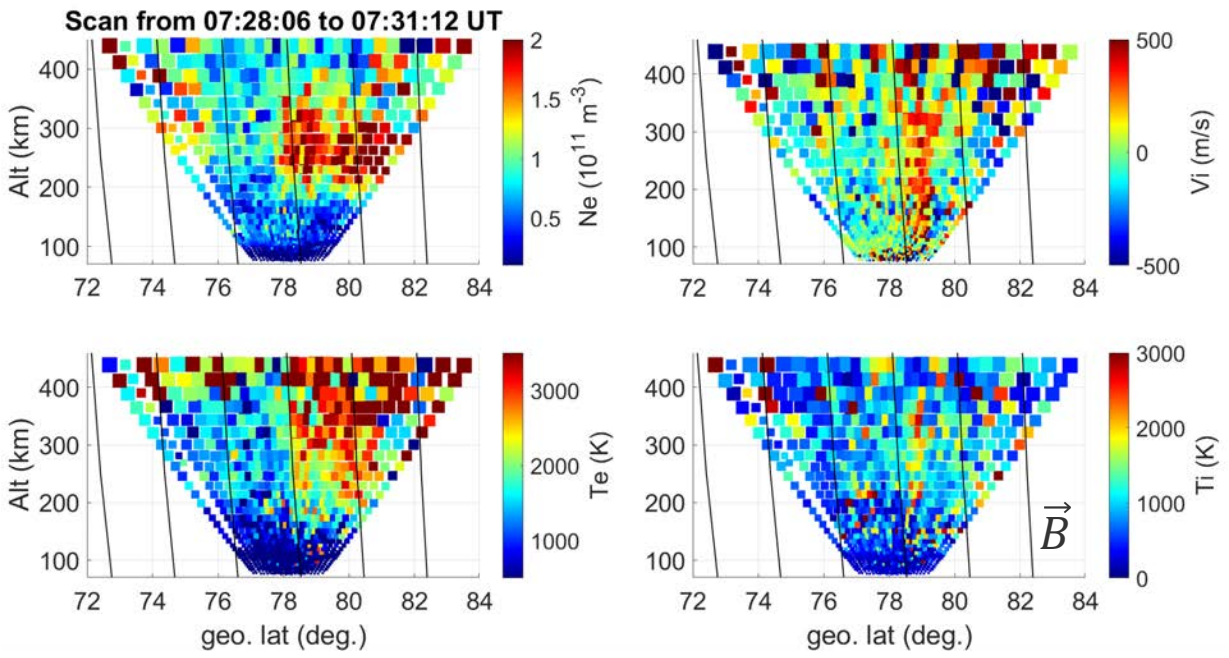
THE PLASMA PARAMETERS



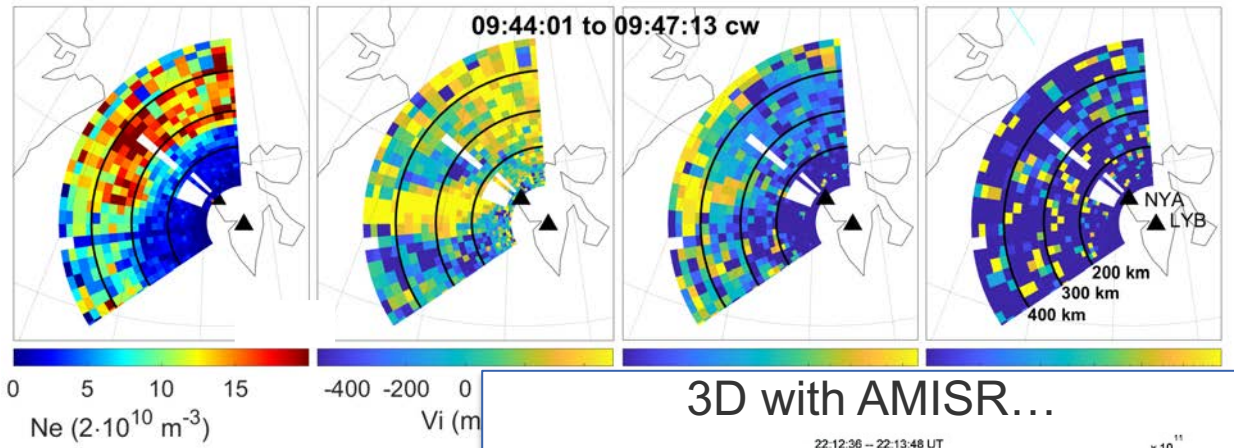
SPACE-TIME:SCANNING CAPABILITIES

«Mechanical» scans: EISCAT Svalbard 32m

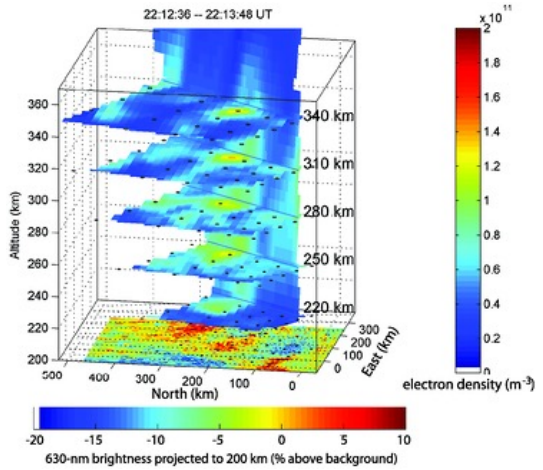
Elevation scans



Azimuthal scans



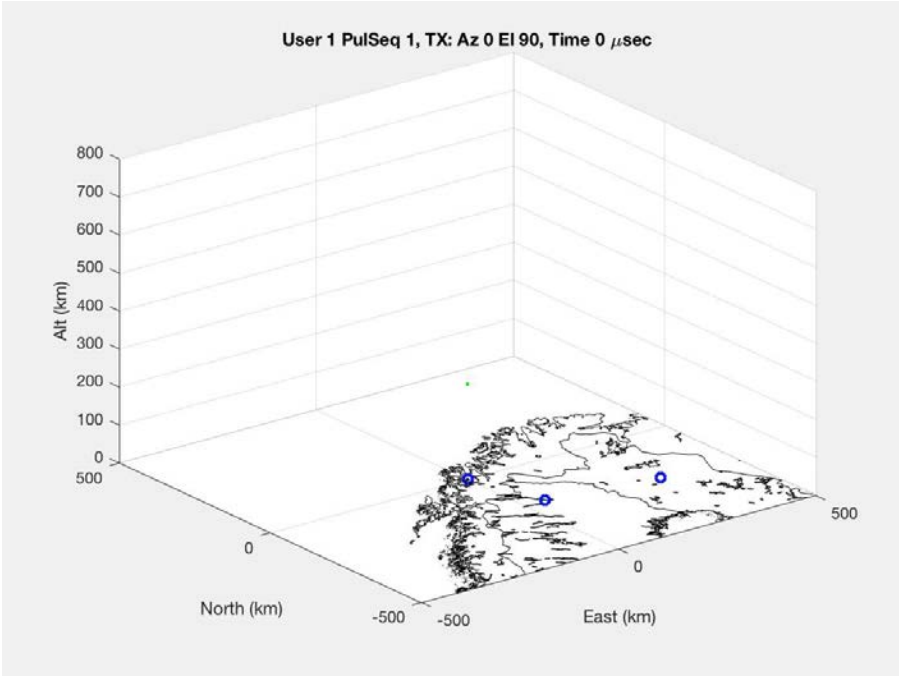
3D with AMISR…



Dahlgren et al. (2012), GRL, doi:10.1029/2012GL050895.

EISCAT 3D (E3D)

- **Phased array** radar @VHF (233 MHz)
- First stage: 3 sites
  - E3D “Core site” in Skibotn, Norway
  - E3D Receivers:
    - Kaiseniemi, Sweden
    - Karesuvanto, Finland

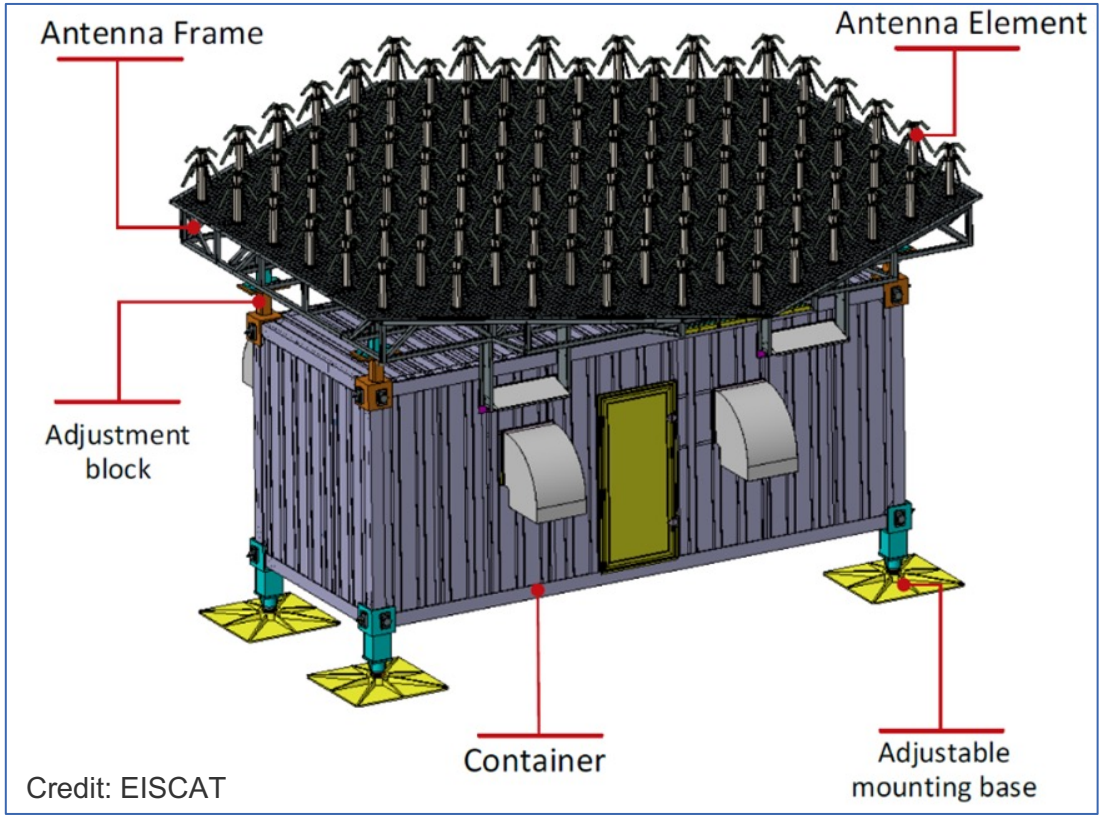


https://eiscat.se/eiscat3d-information/eiscat_3d-operation-illustration/

E3D SITES DESIGN

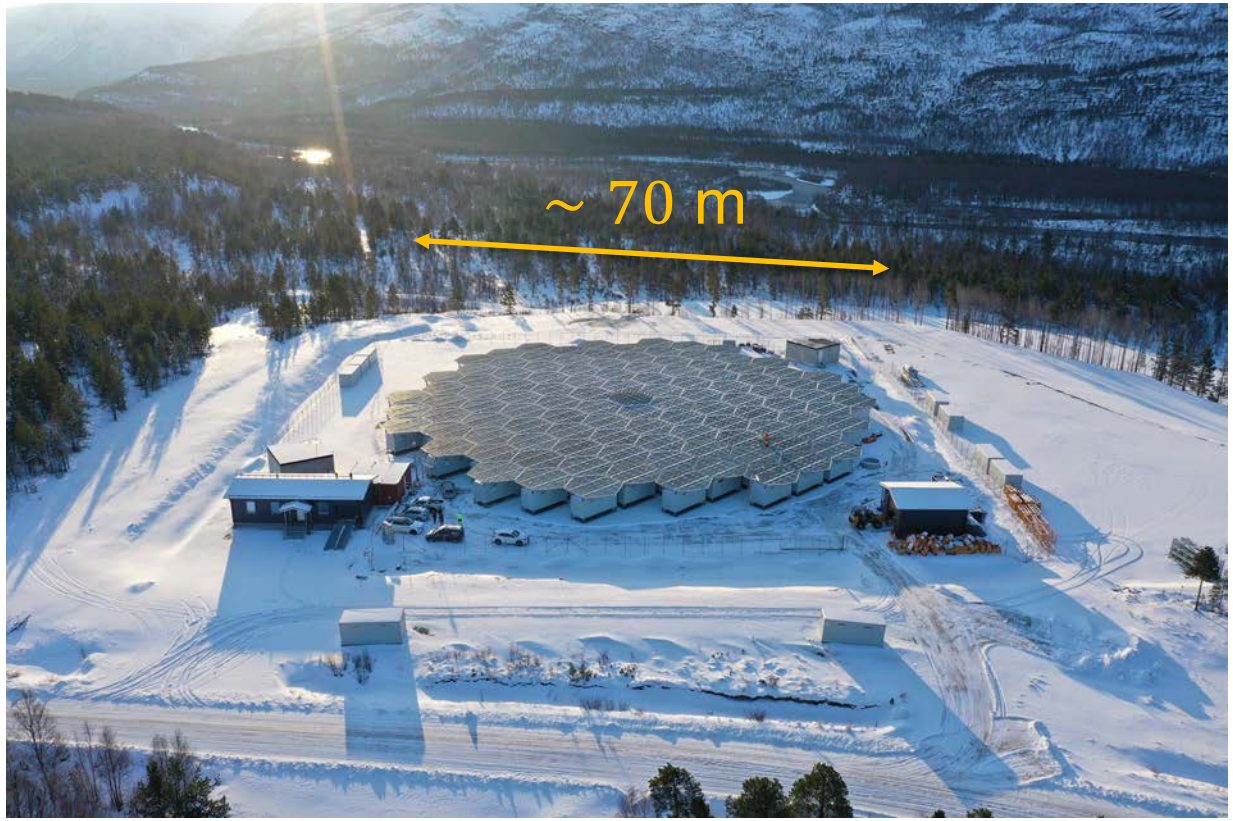
Antenna Unit (AU)

(91 per AU)



Credit: EISCAT

“Honeycomb” pattern



Skibotn site in February 2023. Credit: EISCAT

: 119 AUs including 10 outriggers for calibrations → 9 919 + 910 dipole antenna elements.
: 55 AUs → 5 005 dipole antenna elements.
: 54 AUs → 4 914 dipole antenna elements.

STATUS: SKIBOTN, NORWAY

Completed:

- All 109 antenna units are installed.
- Site buildings.
- Calibration towers.

Ongoing:

- Installation of Antenna Elements, casings etc.
- Power and fiber distribution startup (June 5).

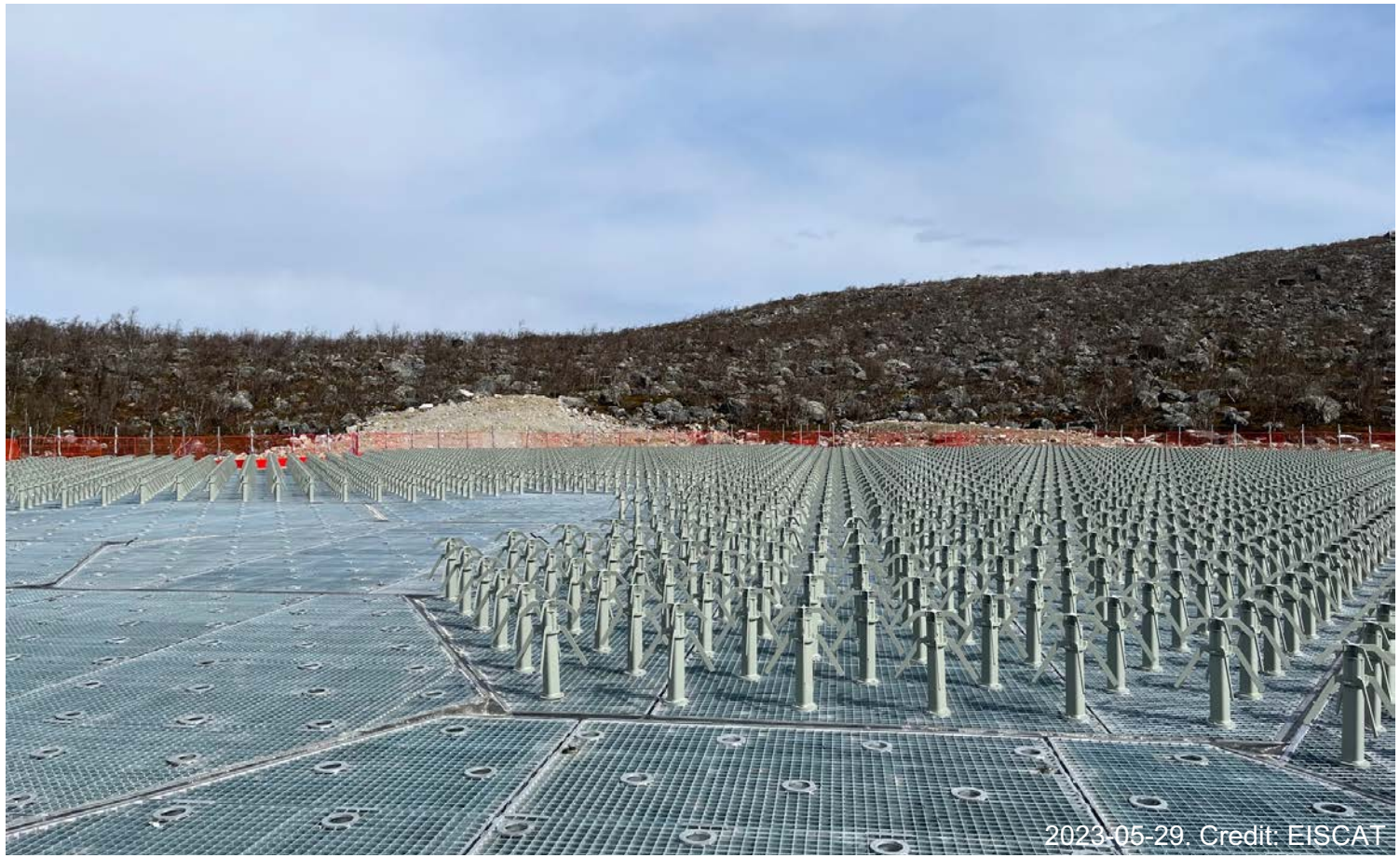
Next:

- Installation of 10 outriggers.
- RF-fence installation starts in August.
- Erosion problem (re-vegetation, extend trenches).

Autumn 2023: Installation of the PET-7 configuration: Seven Transmit/Receive AUs, network equipment etc.

First Light monostatic campaign

STATUS: KAISENIEMI, SWEDEN



Completed:

- All 55 antenna units are installed.
- Nets and casings completed.
- Site buildings completed (final inspection soon).
- Transformer installation.

Ongoing:

- Power supply installation (completed by 1 August).
- Installation of 5.000 dipole antenna elements.
- Calibration towers installation
- Power and fiber distribution

2023-05-29. Credit: EISCAT

Next: Installation of Receivers, network etc.

KARESUVANTO, FINLAND

2023-05-15 Credit: EISCAT

Completed:

- All 54 antenna units are installed.
- Antenna Elements installed.
- Nets and casings.
- Site buildings.
- Transformer.

Ongoing:

- Focus on Kaiseniemi – no activities.

Next:

- Power and fiber distribution (signed agreement).
- Calibration towers installation.
- Installation of Receivers, network etc.

CAPABILITIES

Volumetric imaging and tracking

Interferometric imaging

Multi-static imaging

Greatly improved sensitivity

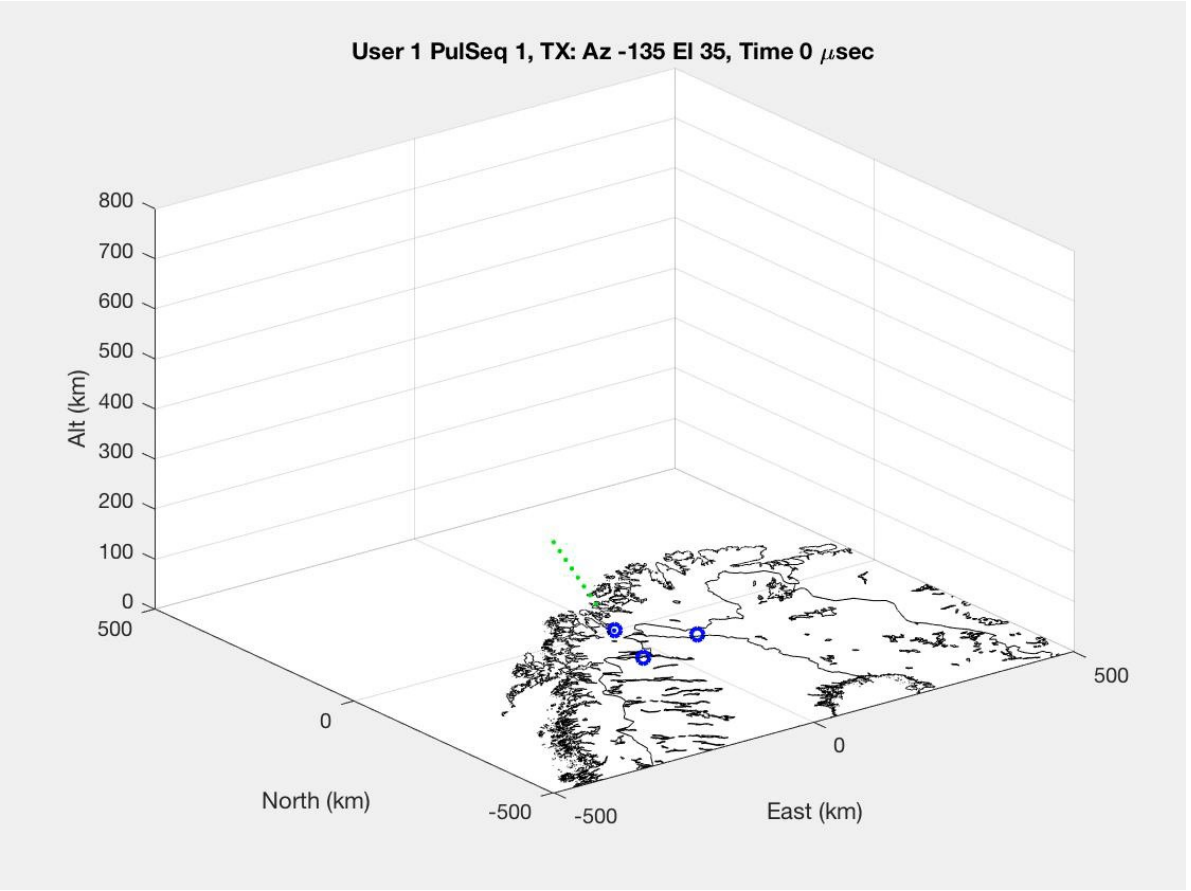
Transmitter flexibility

Credit: J. Svensson, EISCAT

VOLUMETRIC IMAGING AND TRACKING

Beam forming

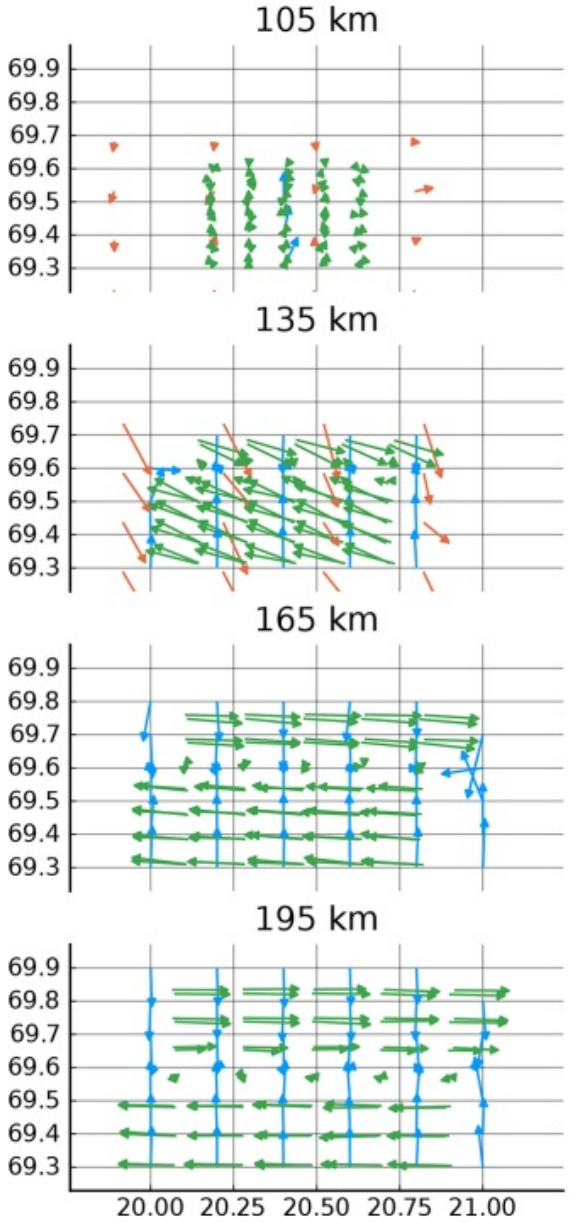
- Capability to “scan” rapidly between different pointing directions or cover different regions simultaneously.
  → Volumetric imaging
  → Satellite and space debris tracking



https://eiscat.se/eiscat3d-information/eiscat_3d-operation-illustration/

More info: McCrea et al. (2015)/eiscat.se

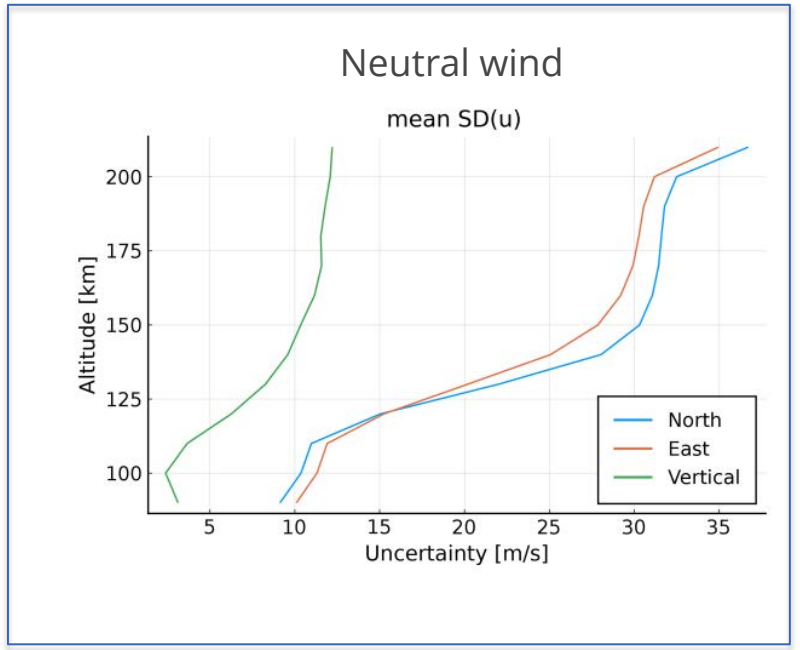
MULTI-STATIC IMAGING

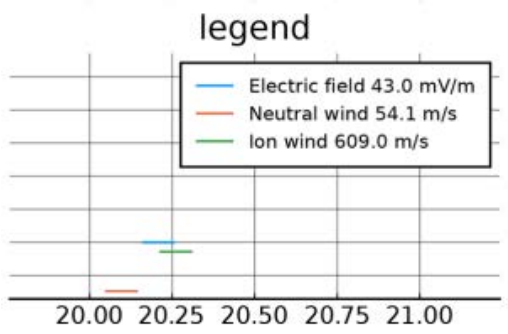


Design: Two receivers at ~ 120 km & ~ 250 km from the core
→ Allows for full **3D measurements of vector quantities**

Example of technique for resolving the E-field and neutral wind from E3D volumetric measurements of ion velocity:

→ Accurate estimates of E-fields at altitudes above 110-120 km (a few mV/m).
→ Neutral wind can be resolved below about 120 km.





Study and Figures (adapted from): Stamm, J., Vierinen, J., Gustavsson, B., and Spicher, A. (2023): A technique for volumetric incoherent scatter radar analysis, Ann. Geophys., 41, 55–67, https://doi.org/10.5194/angeo-41-55-2023

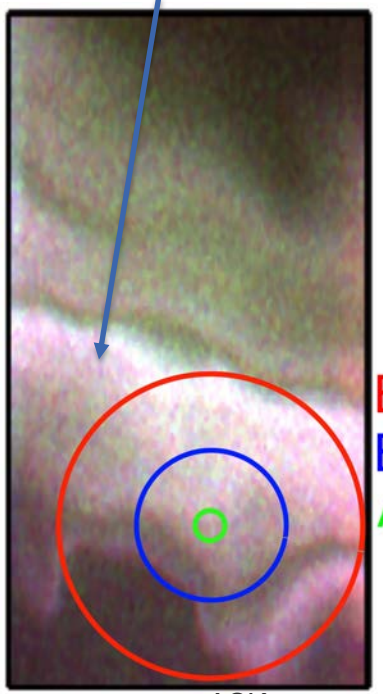
INTERFEROMETRIC IMAGING

Aperture synthesis imaging

Dividing the arrays into smaller elements → **resolve sub-beamwidth structures of the order of 20 m.**

For the E-region

Auroral arc structure (optical emission)



Beam width

EISCAT 3D

EISCAT UHF

Arecibo

Temporal scales

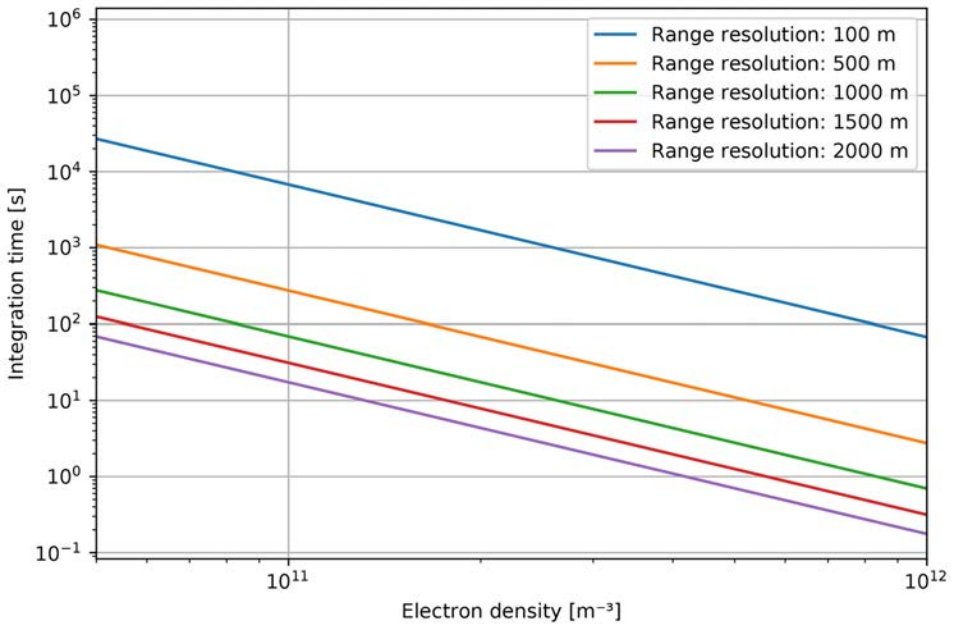
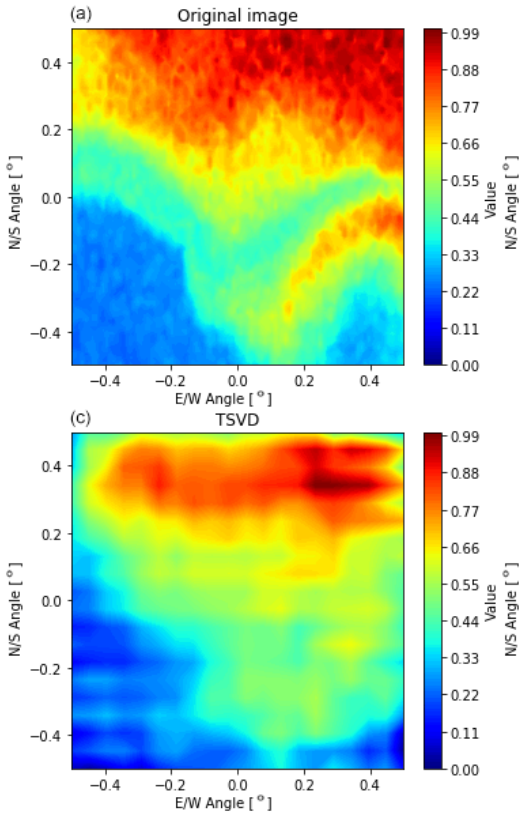


Image reconstruction



Resolve structures ~ 90×90 m (10 s resolution)

Source study and figures: Stamm, J., Vierinen, J., Urco, J. M., Gustavsson, B., and Chau, J. L. (2021), Ann. Geophys., doi: https://doi.org/10.5194/angeo-39-119-2021

EXAMPLE OF SCIENTIFIC TOPICS FOR E3D (WITHIN SPACE AND PLASMA PHYSICS)

See: McCrea, I., et al. (2015): The science case for the EISCAT_3D radar, Prog. Earth Planet. Sci., 2, 21

3D volumetric imaging of essential plasma parameters and 3D measurements of vectors @ high resolution

New insights: Space-time variability, ITM coupling, energy deposition & dissipation, Multi-scale processes,…

Small-scale structures

Example of relevant topics

→ **Ionospheric & auroral dynamics**: meso-scale convection, flow channels, 3D structures of ionospheric currents, Naturally Enhanced Ion Acoustic Lines (NEIALs), …

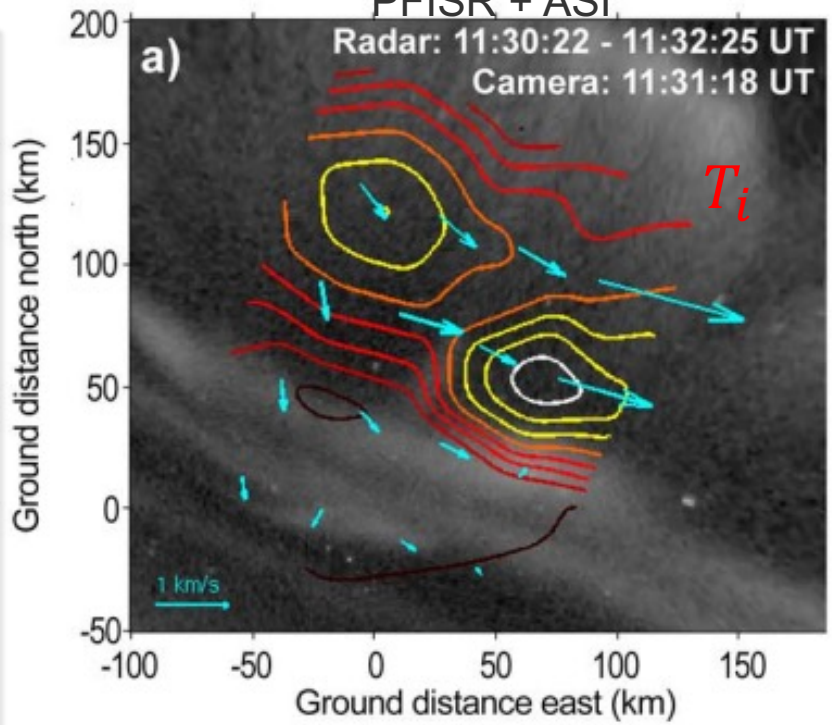
→ **Plasma turbulence and structuring**: patches, blobs, development and evolution of irregularities, polar mesospheric echoes, …

→ Space debris, meteors etc.

& Increase science outcome combining with other instrumentation such as satellites/sounding rockets, cameras, magnetometers, GNSS receivers, …

Etc.

PFISR + ASI

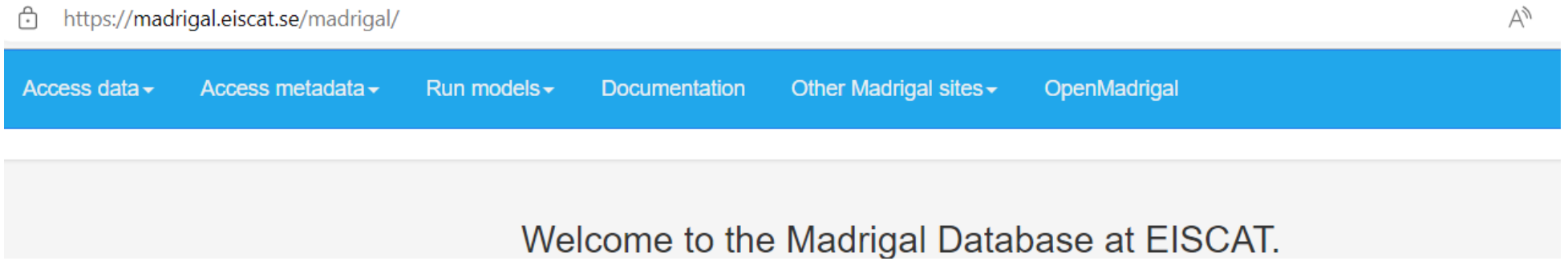


After Semeter, J., et al. (2010),doi:10.1029/2009JA014931.

HOW TO ACCESS EXISTING EISCAT DATA

RULE OF USE: Use of archived raw & analyzed Common and Special Program (more than one year old) data generally OK + Acknowledgement. See “rule of use” for official regulations: https://eiscat.se/scientist/data/

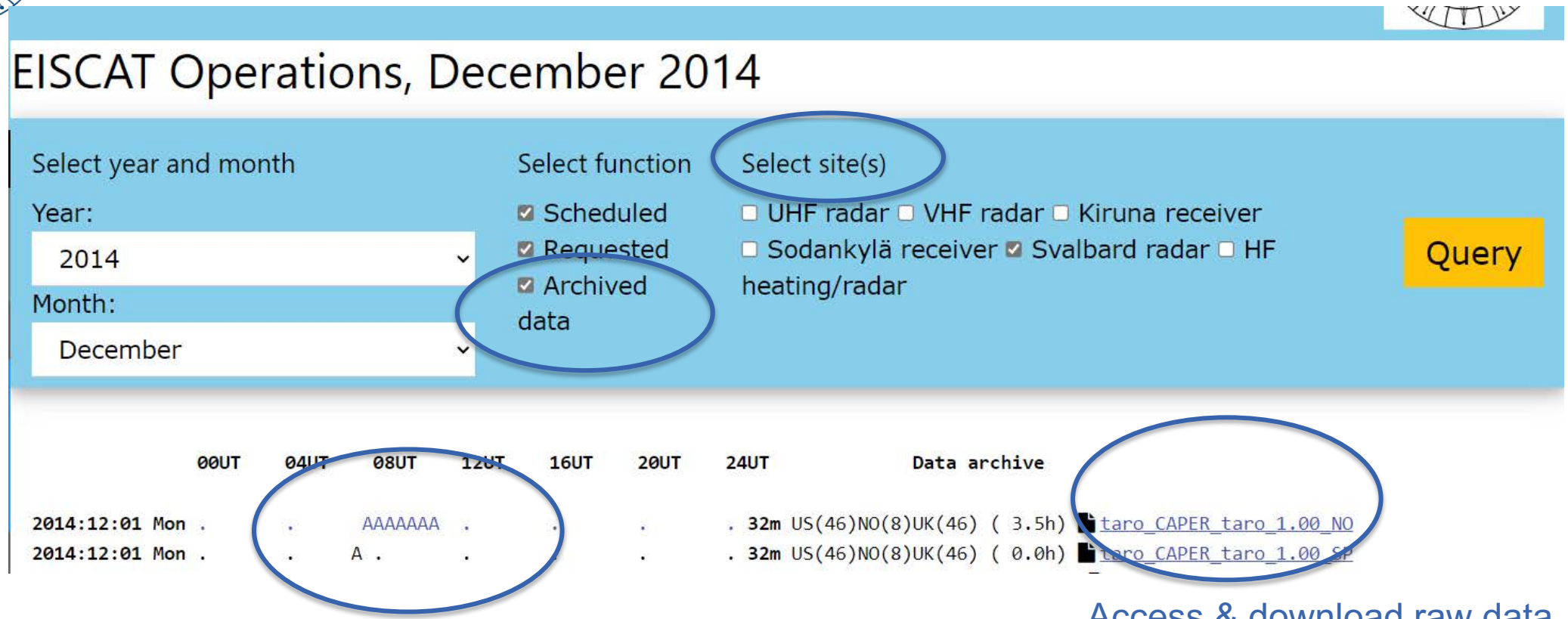
- Madrigal (1min integration time)



- Quicklooks & Raw data: https://portal.eiscat.se/schedule/
  Data can be accessed unauthenticated. (EISCAT is moving towards user authentication)

- E3D: Currently under development

HTTPS://PORTAL.EISCAT.SE/SCHEDULE/



Quicklooks and plasma parameter data

Access & download raw data

Raw data can be re-analyzed e.g., using GUISDAP (Software based on MATLAB)

https://eiscat.se/scientist/user-documentation/guisdap/

Info about the different experiments: https://eiscat.se/wp-content/uploads/2021/03/Experiments_v20210302.pdf

EISCAT RADAR SCHOOL

https://www.sgo.fi/Events/RS2023/

Sodankylä Geophysical Observatory

Radar School: | Registration | Venue & Travel | Programme | Literature

International EISCAT Radar School
14 – 19 August 2023
Kilpisjärvi, Finland

The **International EISCAT Radar School** is a training course for new users of incoherent scatter radars at any stage of their research career. Participants should have a background in space physics, ionospheric pysics, plasma physics, or radar (radio science). The school will cover all essential aspects of the current incoherent scatter radar systems, including the science programme. An overview of the existing hardware and software was provided and future plans will be discussed, with an emphasis on phased array radars in preparation of EISCAT_3D.

The course will have a very strong emphasis on practicals, i.e. work in groups of participants on real data. There will be dedicated radar experiments for every group, and the groups will analyse their data and present their results under the guidance of an experienced team of instructors.

The radar school is organised by the Sodankylä Geophysical Observatory, the Space Physics and Astronomy Research Group (both University of Oulu), and the EISCAT Scientific Association.

The radar school is part of the University of Arctic Thematic Network Arctic Space Hub.

Registration

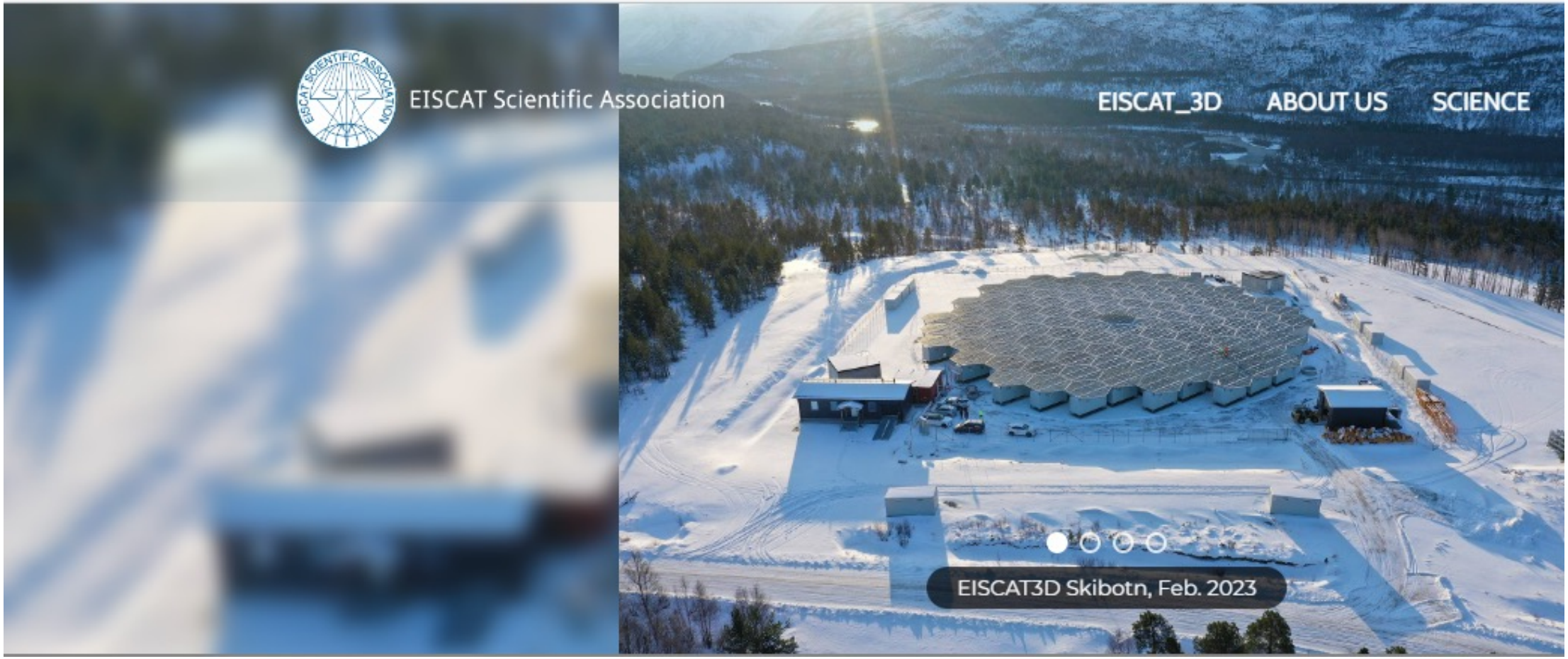
Please visit the Registration page for more information.

UNIVERSITY OF OULU

UArctic

MORE INFORMATION: EISCAT.SE

https://eiscat.se/eiscat3d-information/eiscat_3d-design-and-science/



https://eiscat.se/category/newsletters/

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- https://eiscat.se/wp-content/uploads/2022/02/EISCAT-report-2019-2020_compressed.pdf
- https://eiscat.se/scientist/user-documentation/guisdap/

Thank you for your attention!