UiT The Arctic University of Norway

EISCAT 3D

Status and future development

Andres Spicher[1], Axel Steuwer[2], Devin Huyghebeart[1], Yasunobu Ogawa[3], Juha Vierinen[1], Johann Stamm[1], Ingrid Mann[1], and Njål Gulbrandsen[4]

[1]UiT The Arctic University of Norway, Tromsø, Norway
[2]EISCAT Scientific Association, Kiruna, Sweden
[3]National Institute of Polar Research, Tokyo, Japan
[4]Tromsø Geophysical Observatory (TGO), Tromsø, Norway.

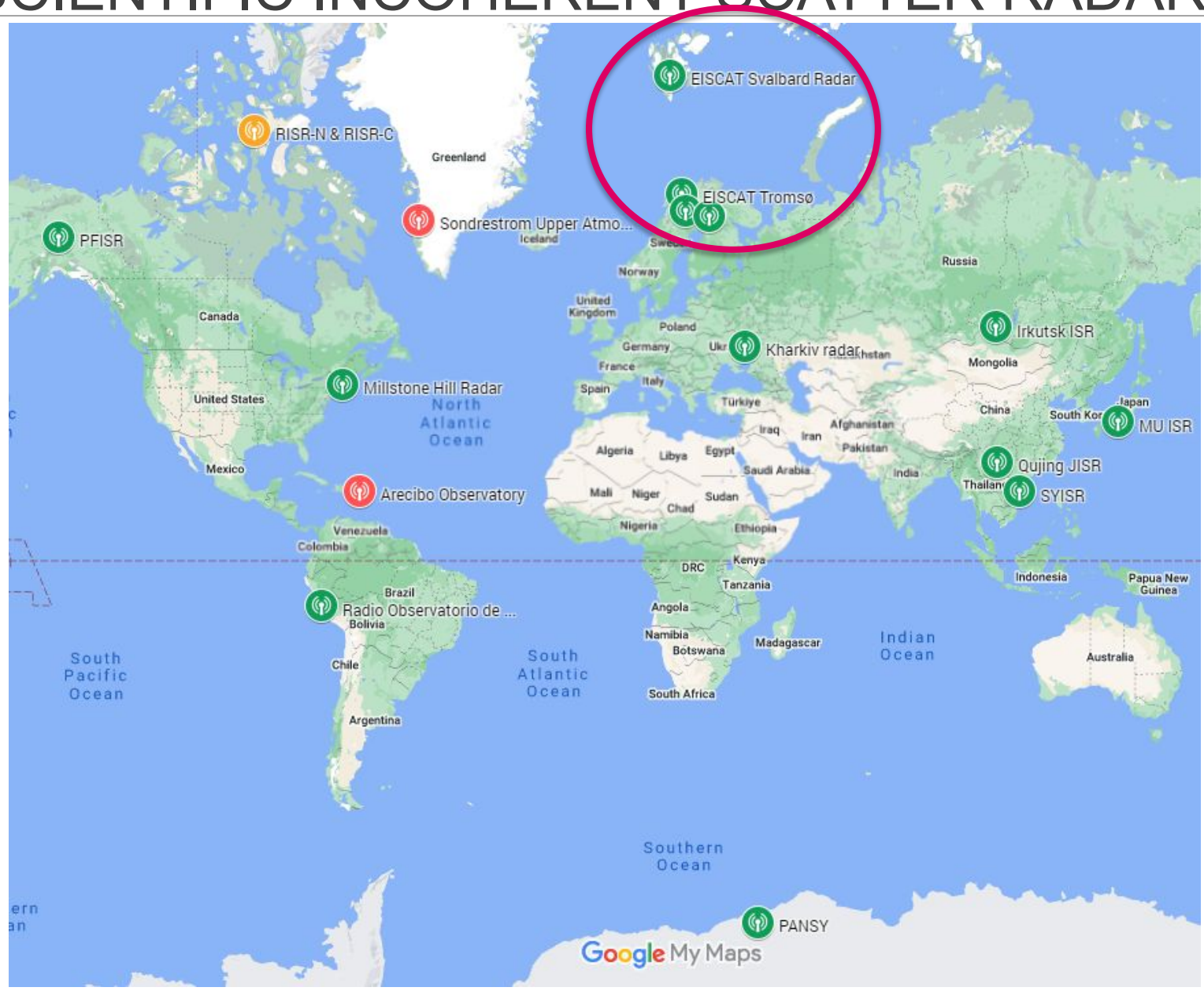
Source: eiscat.se

AS acknowledges funding from the Research Council of Norway (RCN) grant 326039 and from UiT The Arctic University of Norway contribution to the E3D project funded by the RCN (research infrastructure grant 245683).

TABLE OF CONTENTS

- International EISCAT Scientific Association
- EISCAT 3D:
  - Status
  - Future development and operations
  - Examples of capabilities
- Options for participation for the international community

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)

EISCAT ORGANIZATION

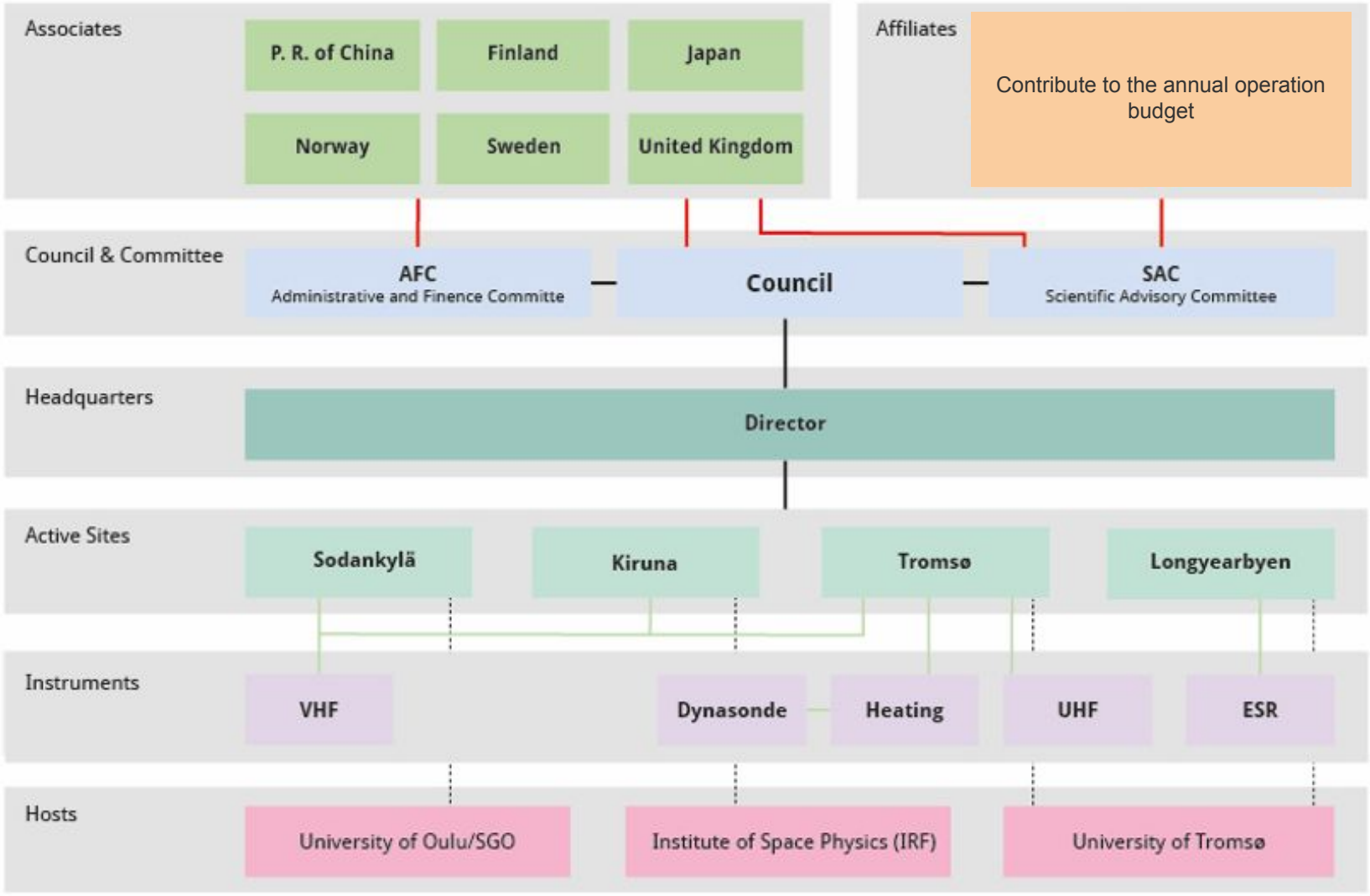
Norwegian organization

RCN - Associate

E3D Norway

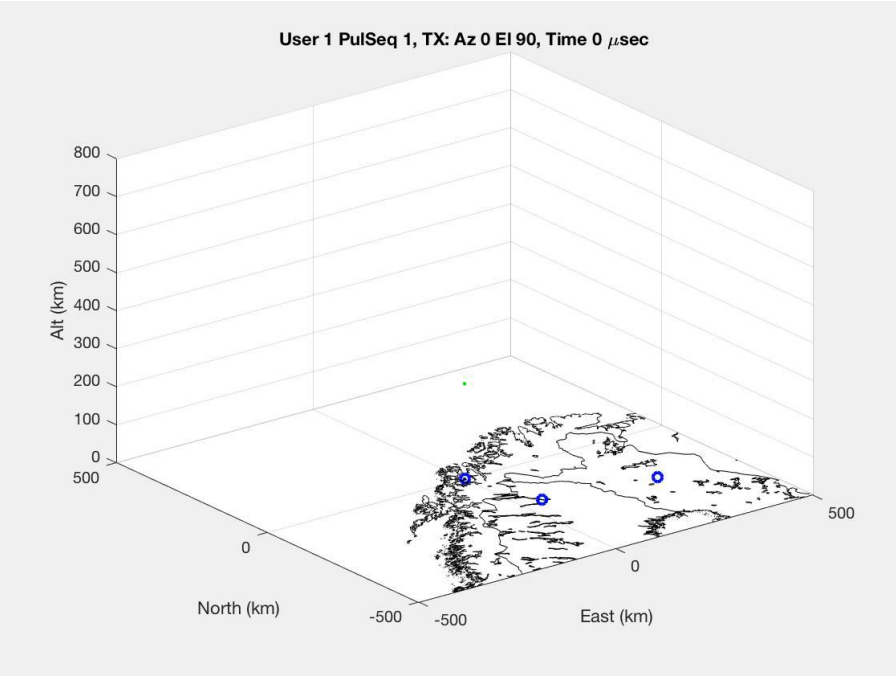
- UiT
- NTNU
- UNIS
- UiO
- UiB
- Andøya Space

EISCAT Organization (2022)



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

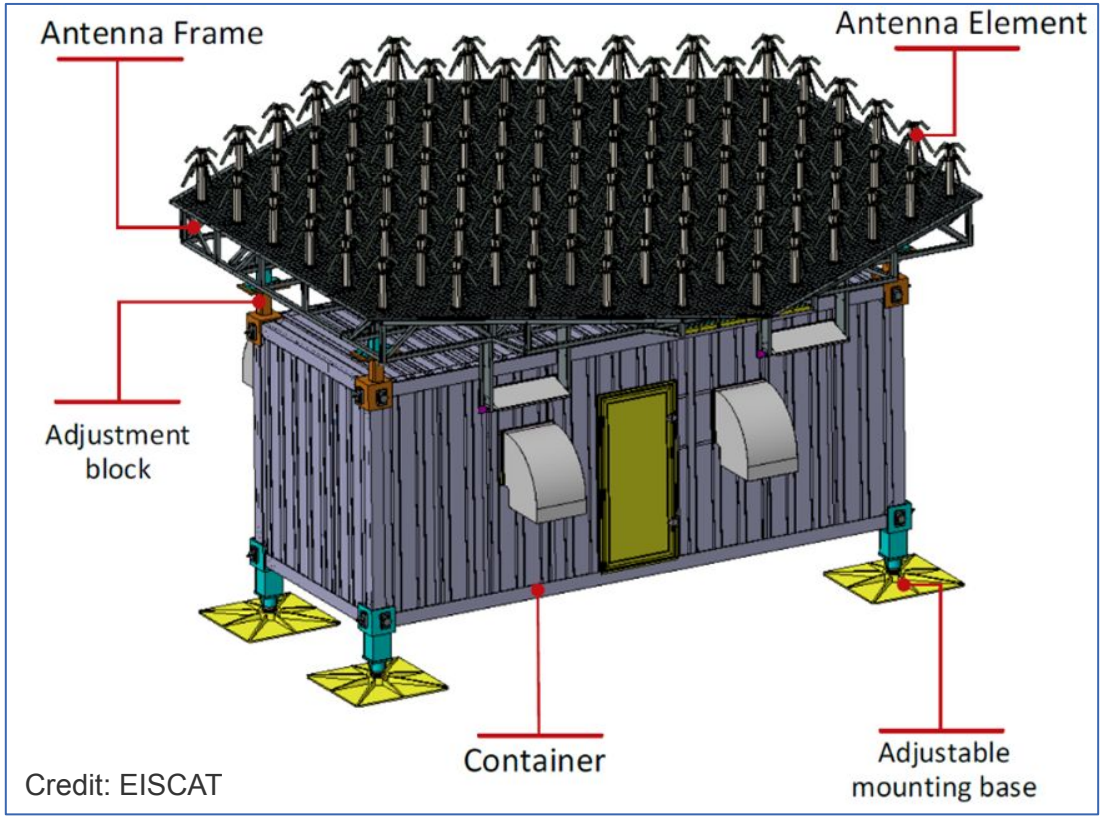


https://eiscat.se/eiscat3d-information/eiscat_3d-operation-illustration/

E3D SITES DESIGN

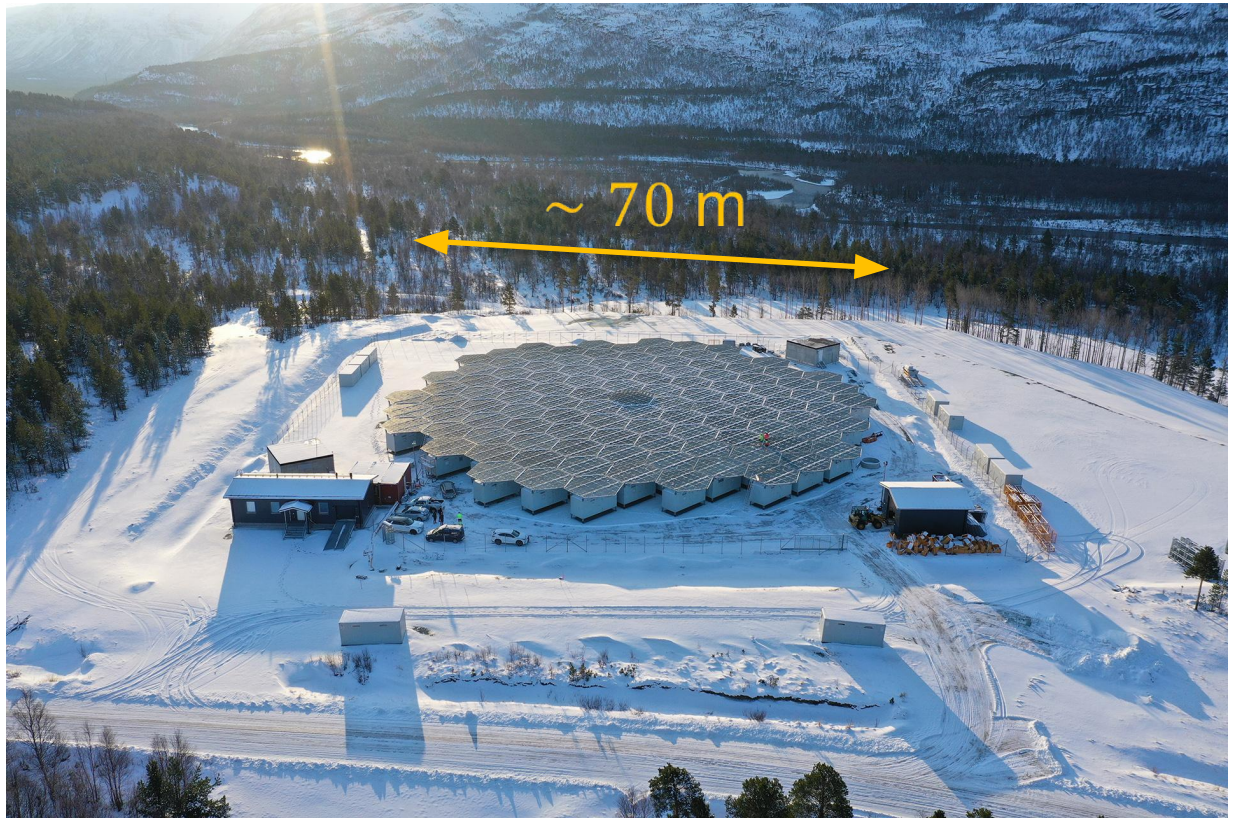
Antenna Unit (AU)

(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).

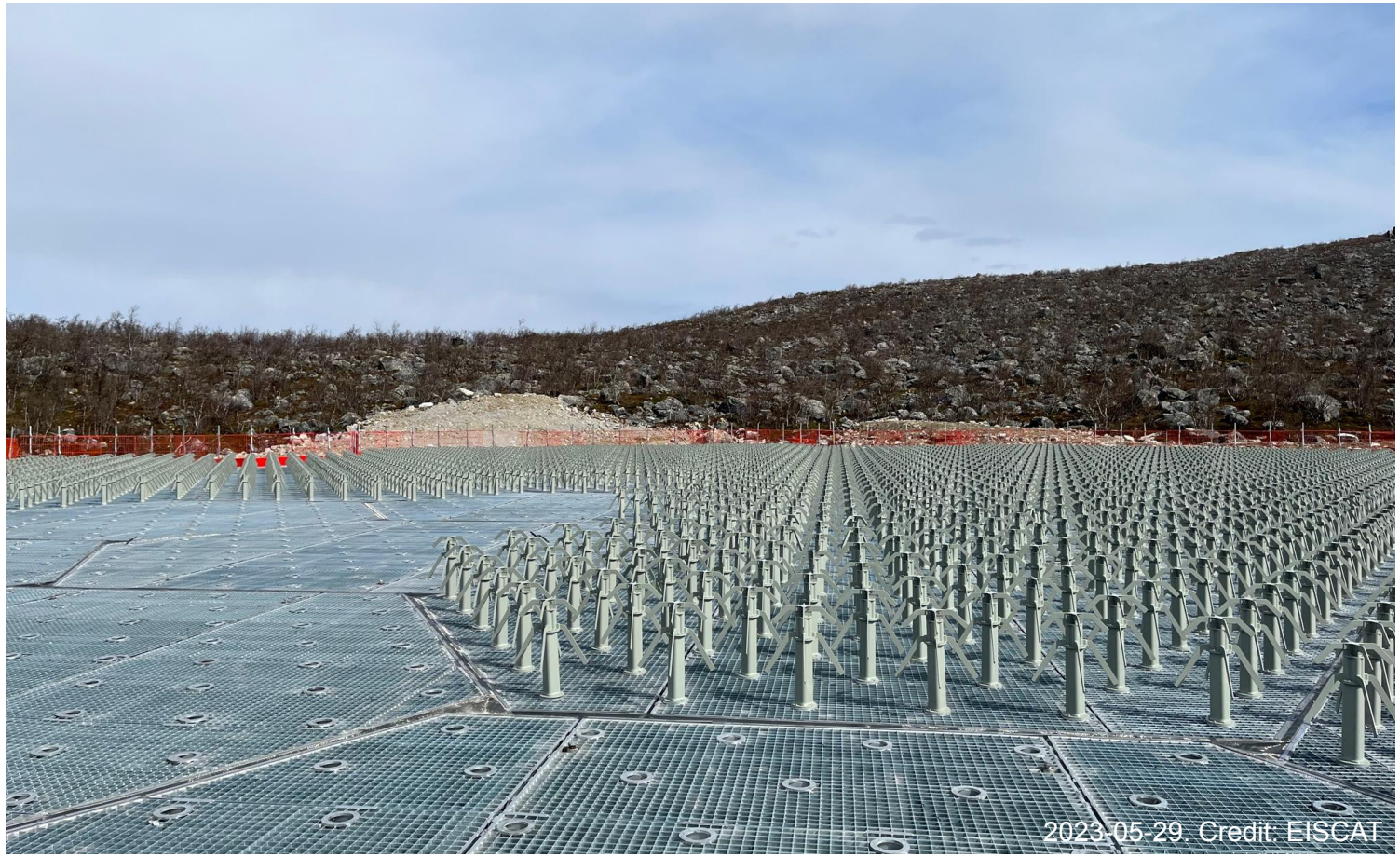
Next:

- 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.

E3D DATA CENTER

SUNET is a division of the Swedish Research Council and provides secure and stable national infrastructure for data communication and identity management and is part of the global research infrastructure.

Placement: In SUNET's new data center *DC Orion* located in a former sawmill area in Karlsborg outside Kalix, Sweden.

Physical security: Class 3 (MSB).

Data security: Dedicated E3D fiber passes here.
Reliability: Cooling, power, redundancy.

Status: Is being built now, available for E3D in autumn 23.

FUTURE DEVELOPMENT

Construction

- Stage 1: Three sites (on-going)
  Aim: Monostatic 2023 (Q4)
- Stage 2: Transmitter upgrade to 10 MW
- Stage 3: Forth site (system considered “fully implemented”)
- Stage 4: Fifth site added

Science

Suggested chronological planned operations:

1. First light (Fall 2023) & validation of initial data.
2. Common Program (CP) observations.
3. Special Program (SP) observations (researchers from EISCAT Associates and Affiliates).

Multi-directional observations

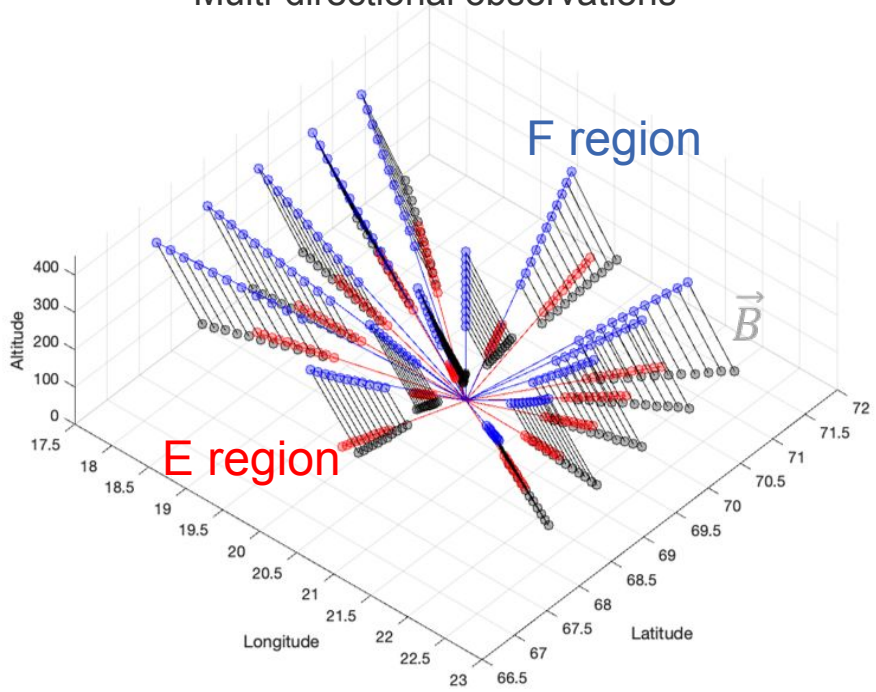


Figure from “E3D CP recommendations”

Completed:

- List of recommended common programs established (based on current EISCAT CP programs) and use GUISDAP initially to get the basic plasma parameters.

Next:

- Recommendation discussed and modified by several committees and the user community.
- “Software working group“ materializes recommendation.

See "Official draft of recommendations for E3D CP observations"
https://drive.google.com/file/d/1a0gcqghGt73AOmWQm_PCAH9x7Rj2CYRr

Info about EISCAT experiments: https://www.eiscat.se/wp-content/uploads/2017/04/Experiments.pdf

CAPABILITIES

Volumetric imaging and tracking

Multi-static imaging

Interferometric imaging

Greatly improved sensitivity

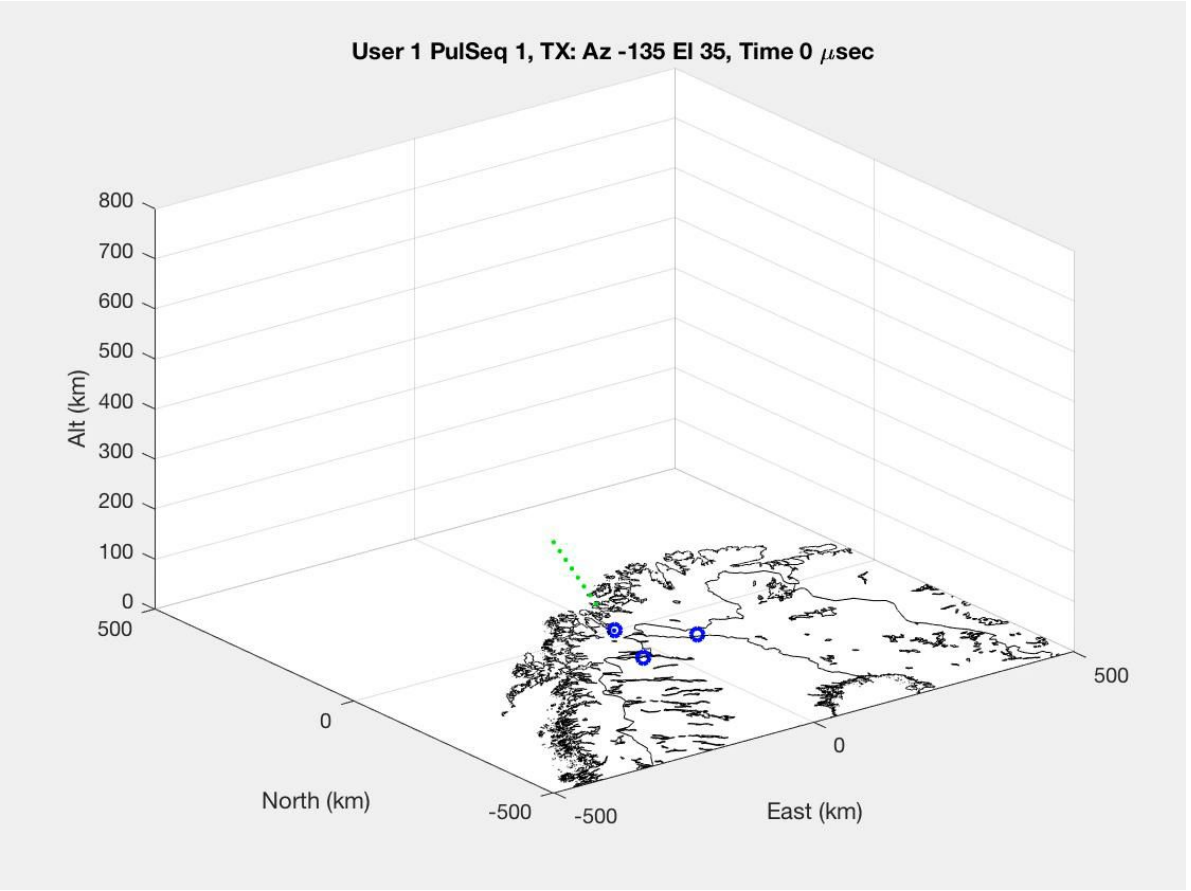
Transmitter flexibility

Credit: J. Svensson, EISCAT

VOLUMETRIC IMAGING AND TRACKING

Beam forming

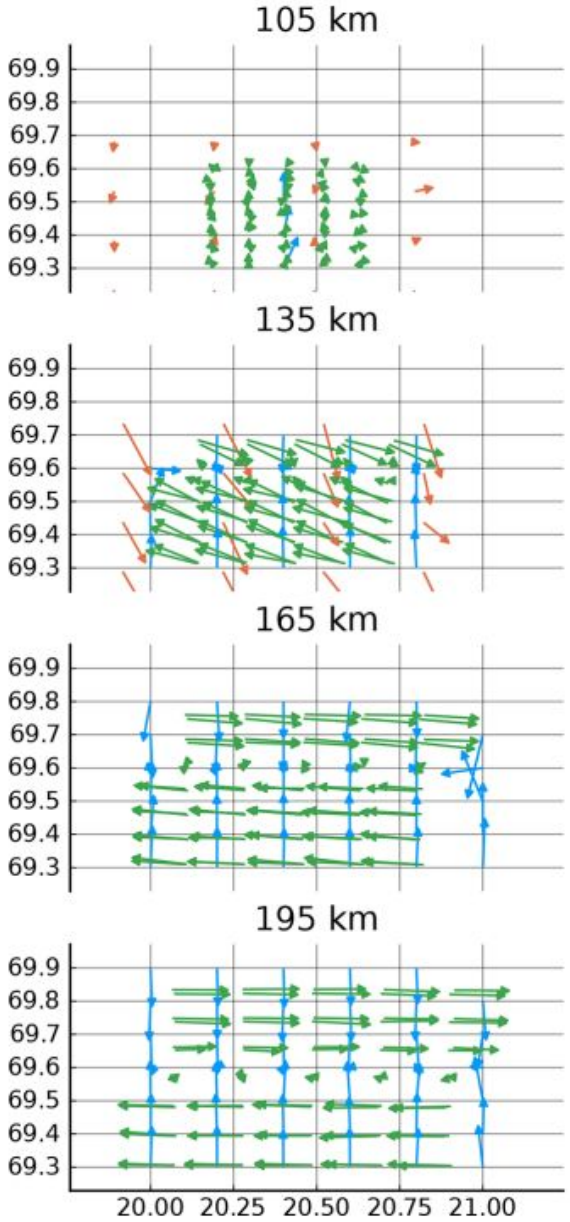
- Capability to “scan” rapidly between different pointing directions or cover different regions simultaneously.
  → **Volumetric imaging**
  → **Satellite and space debris tracking**



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

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

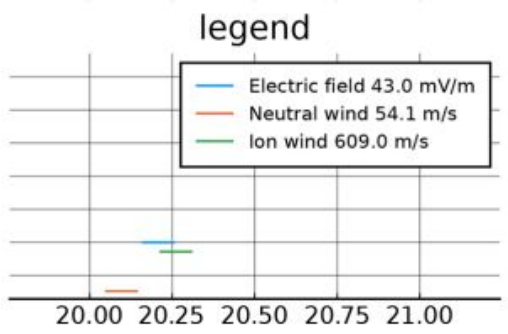
MULTI-STATIC IMAGING

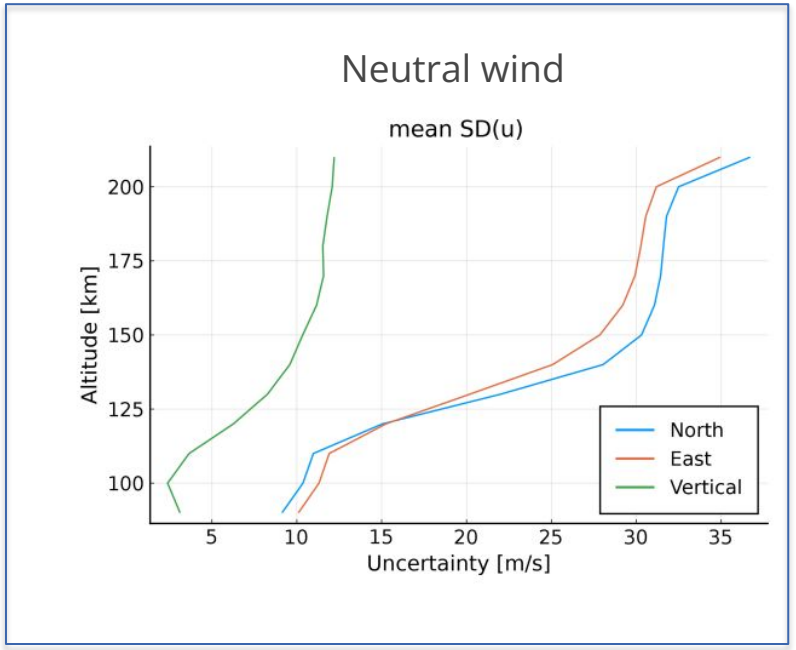


Design: Two receivers at ~ 120 km + ~ 250 km from the core
→ **Allows for full 3D measurements of vector quantities**

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.





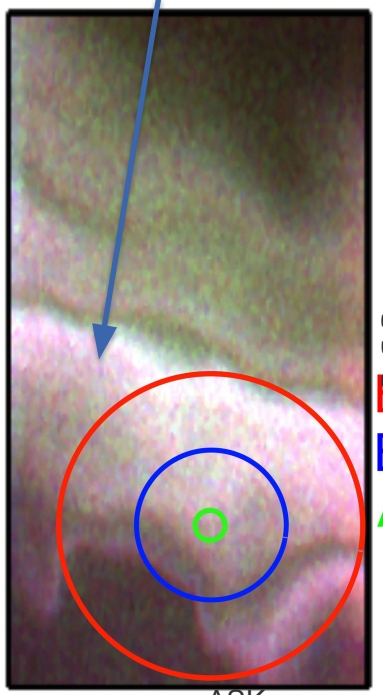
Study and Figures (adapted from): Stamm, J., Vierinen, J., Gustavsson, B., and Spicher, A. (2023): A technique for volumetric incoherent scatter radar analysis, Ann. Geophys., 41, 55–67, https://doi.org/10.5194/angeo-41-55-2023

INTERFEROMETRIC IMAGING

Aperture synthesis imaging

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

Auroral arc structure (optical emission)



For the E-region

Temporal scales

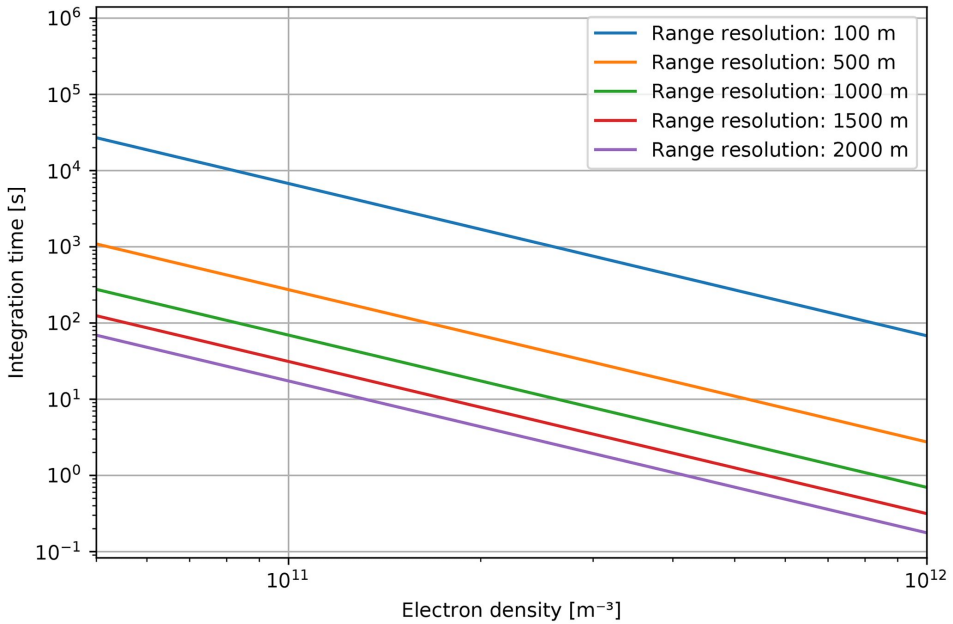
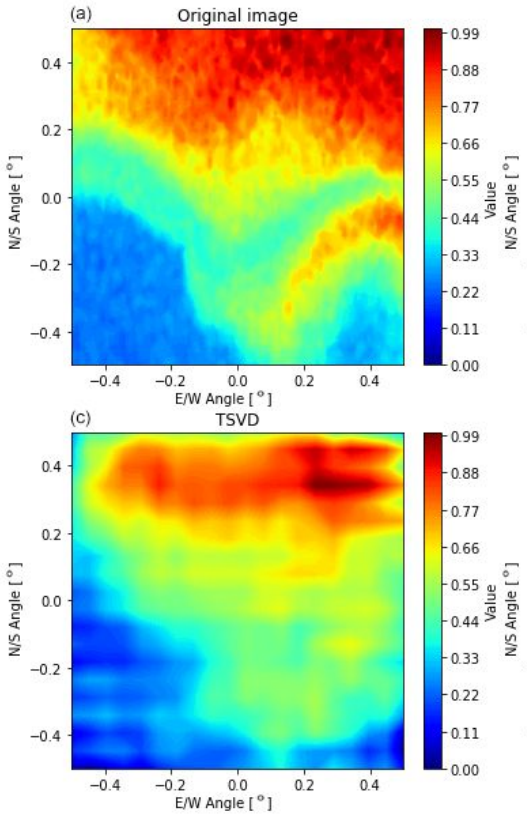


Image reconstruction



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

HOW TO OBTAIN EISCAT TIME/GET INVOLVED

Access and use of EISCAT data:
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/

Obtain EISCAT time for non-«Associate or affiliate countries»:

- Through collaboration with researcher(s) from associate countries.
- «Peer review» application (200 hours per year)

  Two parts
  1) “A free-form 2-4 page science description to concentrate on the scientific value of the proposed work”
  2) “A standard 1-2 page form to define experiment.”

  https://eiscat.se/scientist/access-the-eiscat-facilities/non-membership-countries/

- The PITHIA-NRF Trans-National Access (TNA) Calls*

*PITHIA-NRF (Plasmasphere Ionosphere Thermosphere Integrated Research Environment and Access services: a Network of Research Facilities). https://pithia-nrf.eu/

EXAMPLES OF (NORWEGIAN) E3D RELATED PROJECTS

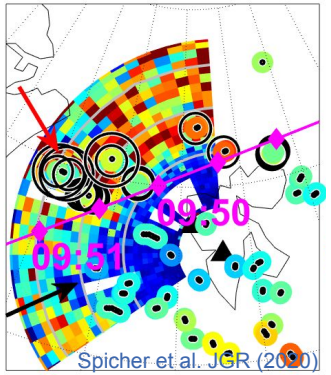
@ UiT The Arctic University of Norway, Tromsø

Contact: andres.spicher@uit.no

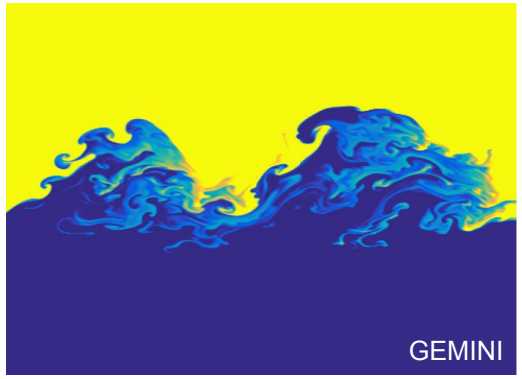
- Assessment of Structuring Connected to Auroral Dynamics using EISCAT 3D (**CASCADE**)

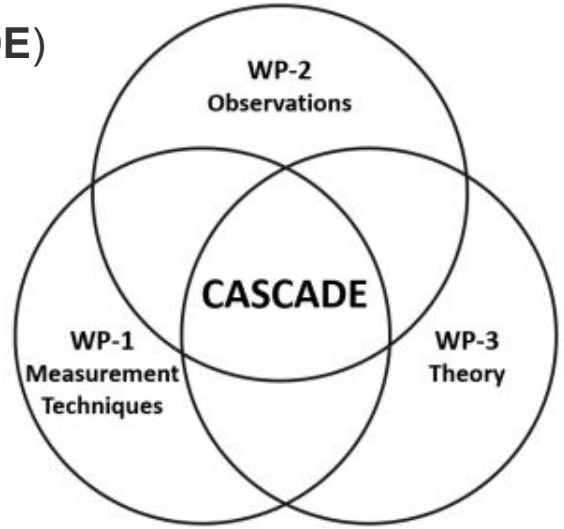
Develop techniques for E3D

Multi-instrument observations



Numerical simulations





Collaboration: Norway (UiT-UiO-UiB) -UK-US

Research project funded by the Research Council of Norway

@ The University of Bergen

Contact: karl.laundal@uib.no

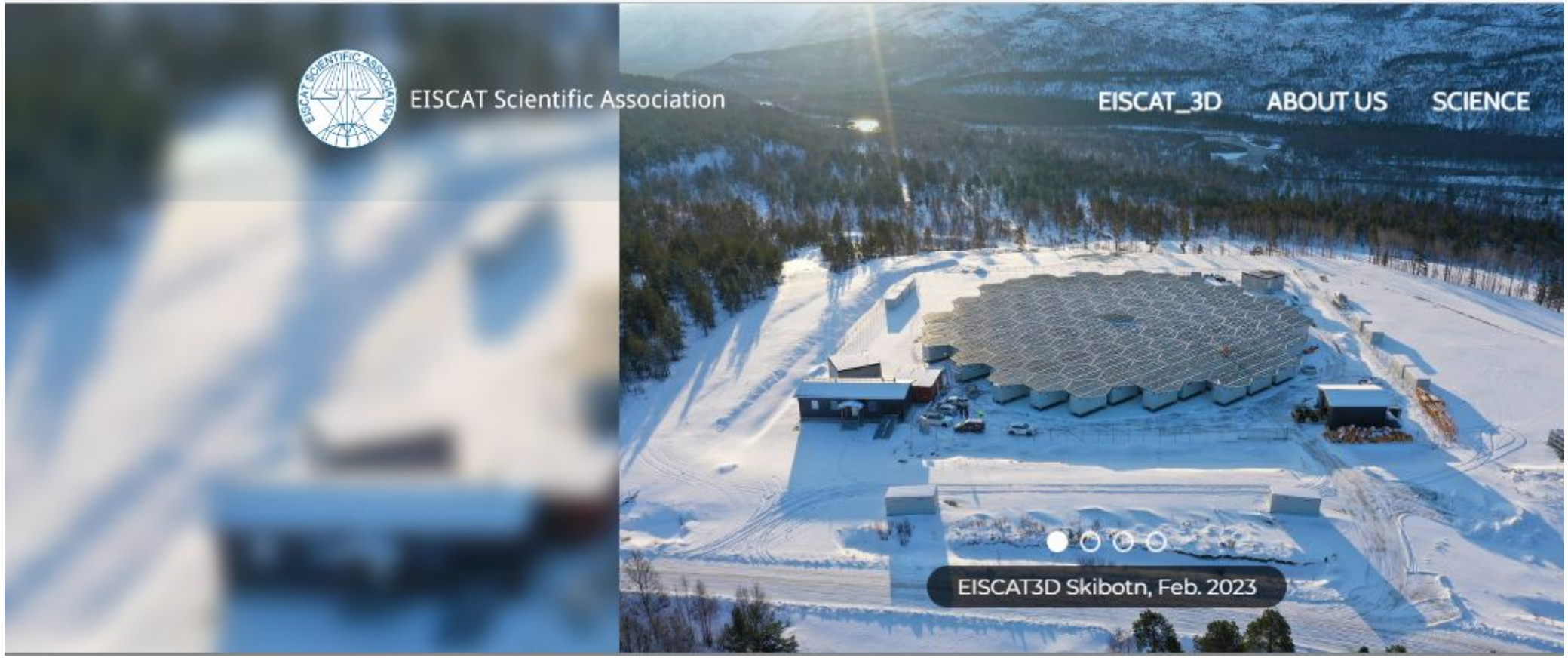
- 3D reconstruction methods based on E3D data
  → Create «synthetic data» which can be used in e.g., OSSE (also part of an ISSI team led by K. M. Laundal)

- “ERC” grant: Project related to ionospheric dynamics that include induction (PI: K. M. Laundal)

And surely many more…from the other countries…

MORE INFORMATION: EISCAT.SE

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



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

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

REFERENCES

- Hashimoto et al., Journal of Atmospheric and Oceanic Technology, First Incoherent Scatter Measurements and Adaptive Suppression of Field-Aligned Irregularities by the PANSY Radar at Syowa Station, Antarctic, 2019 https://journals.ametsoc.org/view/journals/atot/36/9/jtech-d-18-0175.1.xml?tab_body=fulltext-display

- McCrea, I., Aikio, A., Alfonsi, L., Belova, E., Buchert, S., Clilverd, M., Engler, N., Gustavsson, B., Heinselman, C., Kero, J., Kosch, M., Lamy, H., Leyser, T., Ogawa, Y., Oksavik, K., Pellinen-Wannberg, A., Pitout, F., Rapp, M., Stanislawska, I., and Vierinen, J.: The science case for the EISCAT_3D radar, Prog. Earth Planet. Sci., 2, 21, 2015

- Stamm, J., Vierinen, J., Urco, J. M., Gustavsson, B., and Chau, J. L.: Radar imaging with EISCAT 3D, Ann. Geophys., 39, 119–134, https://doi.org/10.5194/angeo-39-119-2021

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

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

Thank you for your attention!