Status and Highlights - 2019

BIRKELAND CENTRE FOR SPACE SCIENCE

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Abstract

The following is a summary for the activity at the Kjell Henriksen Observatory (KHO) in 2019. The current active personnel of the observatory are presented together with the operational instruments. The activity has been high due to the Grand Challenge Initiative (GCI) rocket campaigns. Highlights and achievements are listed together with strategy and future assessments.

(1) The observatory crew

The current crew of KHO is listed below. F. Sigernes headed and had the daily operational responsibility together with Mikko Syrjäsuo.

Name	UNIS position	E-mail
Fred Sigernes	Professor, Optics and atmospheric Research, Head of KHO, Leader Ground-based Instrumentation Group BCSS. Adjunct Prof. NTNU AMOS.	freds@unis.no
Mikko Syrjäsuo	Head engineer	mikkos@unis.no
Noora Partamies	Associate Prof. Middle atmospheric physics	noorap@unis.no
Dag Arne Lorentzen	Professor, Upper polar atmosphere, Head of the Geophysical Department, Principal Investigator (PI) SuperDARN radar project, UNIS node leader of the BCSS	dagl@unis.no
Lisa Baddeley	Associate Professor, Radar applications, Head of the Doppler Pulsation Experiment Co-Investigator (Co-I), SuperDARN radar project	lisab@unis.no
Emma Bland	Post Doc, Middle atmospheric physics	emmab@unis.no
Erkka Heino	Post Doc, Middle atmospheric physics	Erkka.heino@unis.no
Katie Herlingshaw	PhD candidate, Upper atmospheric physics	katie.herlingshaw@unis.no
Lindis Bjoland	Post Doc, Upper atmospheric physics	lindis.bjoland@unis.no
Fasil Tesema Kebede	PhD candidate, Middle atmospheric physics	fasil.tesema@unis.no
Nina Kristine Eriksen	PhD candidate, Upper atmospheric physics	NinaKristine.Eriksen@unis.no

Table 1. The Kjell Henriksen Observatory crew (2019).

Ida Asklund is our contact from the Norwegian Construction and Property Management Department in Longyearbyen who owns the building. Nina Kristine Eriksen is welcomed as new member of the crew.

(2) Teaching and courses

KHO serves as the main laboratory for hands on training and teaching of students in the Space physics group at UNIS.

Fig. 1 shows students on excursion to KHO. Here they are trained on observational techniques, instrument building and introduced to the state-of-the-art facilities for remote observations of the aurora.

Fig.1. First day of fieldwork for AGF-301 students. They successfully forecasted the aurora. Date is February 5 2019. Photo by Emma Bland.

The following 6 courses have used KHO as a part of field work:

Code	Course name	ECTS
AGF-216	The Stormy Sun and the Northern Lights	5
AGF-301/801	The Upper Polar Atmosphere	15
AGF-304/804	Radar Diagnostics of Space Plasma	15
AGF-345/845	Polar Magnetospheric Substorms	10
AGF-210	The middle polar atmosphere	15
AGF-223	Remote sensing and space instrumentation	15

Table 2. UNIS courses using KHO as laboratory (2019)

A grand total of **75 ECTS** (European Credit Transfer and Accumulation System) have been taught.

(3) Operational instrumentation

During the auroral winter season from November to the end of February, 28 optical instruments operate around the clock. The 17 non-optical instruments run all-year-round 24 hours a day.

The instruments at KHO are grouped into mainly five categories (#):

A. All-sky cameras and narrow field of view imagers,
B. Meridian scanning photometers,
C. Spectrometers / spectrographs
D. Scanning / imaging interferometers
E. Radio or non-optical instruments

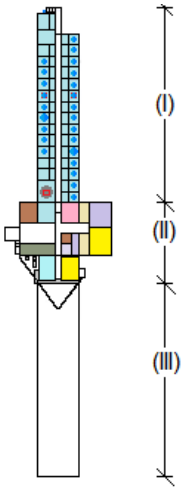


Fig. 2. Sketch of KHO: (I) Instrumental section, (II) Service section, and (III) Extended platform.

A detailed description of the performance and the scientific objective of each instrument are found online. 24 different institutions from 14 nations are present at KHO. Figures 3 and 4 show a map of where the instruments

are located. Table 3 lists all according to institution and category (#).Note that out of 30 instrument domes; 5 are currently not in use.

	Instrument	Institution	#	Country
1	All-sky imager	University of Oslo (UiO)	A	Norway (NO)
2	All-sky intensified video camera	University Centre in Svalbard (UNIS)	A	NO
3	All-sky color camera	University College London (UCL)	A	England
4	All-sky video camera	UNIS	A	NO
5	All-sky DSLR camera	UNIS	A	NO
6	All-sky Airglow Imager	UNIS	A	NO
7	Auroral meridian spectrograph	National Institute of Polar Research (NIPR)	C	Japan
8	Spectrographic Imaging Facility	The University of Southampton/UCL	C	England
9	Meridian-Scanning Photometer	University of Alaska Fairbanks/UNIS	B	USA/NO
10	1m S.Ebert-Fastie spectrometer	University of Alaska Fairbanks/UNIS	C	USA/NO
11	1m G.Ebert-Fastie spectrometer	University of Alaska Fairbanks/UNIS	C	USA/NO
12	1/2m B.Ebert-Fastie spectrometer	University of Alaska Fairbanks/UNIS	C	USA/NO
13	1/2m W.Ebert-Fastie spectrometer	University of Tromsø (UiT)	C	NO
14	Fabry-Perot interferometer	UCL	D	England
15	Scanning Doppler Imager	UCL	D	England
16	Monochromatic Auroral Imager	Polar Research Institute of China (PRIC)	A	China
17	All-sky Airglow Imager	Kyoto University	A	Japan
18	Fluxgate magnetometer	UiT	E	NO
19	2-axis search coil magnetometer	Augsburg College/Univ. of New Hampshire	E	USA
20	Fluxgate magnetometer	PRIC	E	China
21	Auroral Radio Spectrograph	Tohoku University	E	Japan
22	HF acquisition system	Institute of Radio Astronomy/UiT	E	Ukraine/NO
23	64xBeam Imaging Riometer	Danish Meteorological Institute (DMI)/UiT	E	Denmark/NO
24	Balloon Telemetry Station	University of Rome	E	Italy
25	Hyperspectral tracker (Fs-Ikea)	UNIS	C	NO
26	All-sky hyperspectral camera	UNIS	C	NO
27	Narrow field of view tracker	UNIS	A	NO
28	Scintillation and TEC receiver	University of Bergen (UiB)	E	NO
29	Beacon Satellite receiver unit	Finnish Meteorological Institute (FMI)	E	Finland (FI)
30	Automatic weather station	UNIS	E	NO
31	4xWEB cameras (safety)	UNIS	A	NO
32	Celestron 4m Telescope	UNIS	A	NO
33	Internet radio link - Janssonhaugen	NORSAR	E	NO
34	UHF Ground station	National Institute for Aeronautics (LAPAN)	E	Indonesia
35	UHF Ground station	Technische Universität Berlin (TU)	E	Germany
36	All-sky Auroral Imager	Korea Polar Institute (KOPRI)	A	Korea
37	Boreal Auroral Camera Constellation	UNIS (KHO) and UiO (Ny-Ålesund)	A	NO
38	Meridian Imaging Spectrograph	UNIS	B	NO
39	HF Doppler Receiver	UNIS	E	NO
40	3 x GNSS Scintillation Receivers	Nagoya University	E	Japan
41	3 axis induction magnetometer	PRIC	E	China
42	VHF base station	Kongsberg Satellite Service AS (KSAT)	E	NO
43	TESS-W photometer	University of Madrid (UCM)/UNIS	B	Spain/NO
44	2 x Tracker cameras	UNIS	A	NO

Table 3. Instruments at the Kjell Henriksen Observatory (2019).

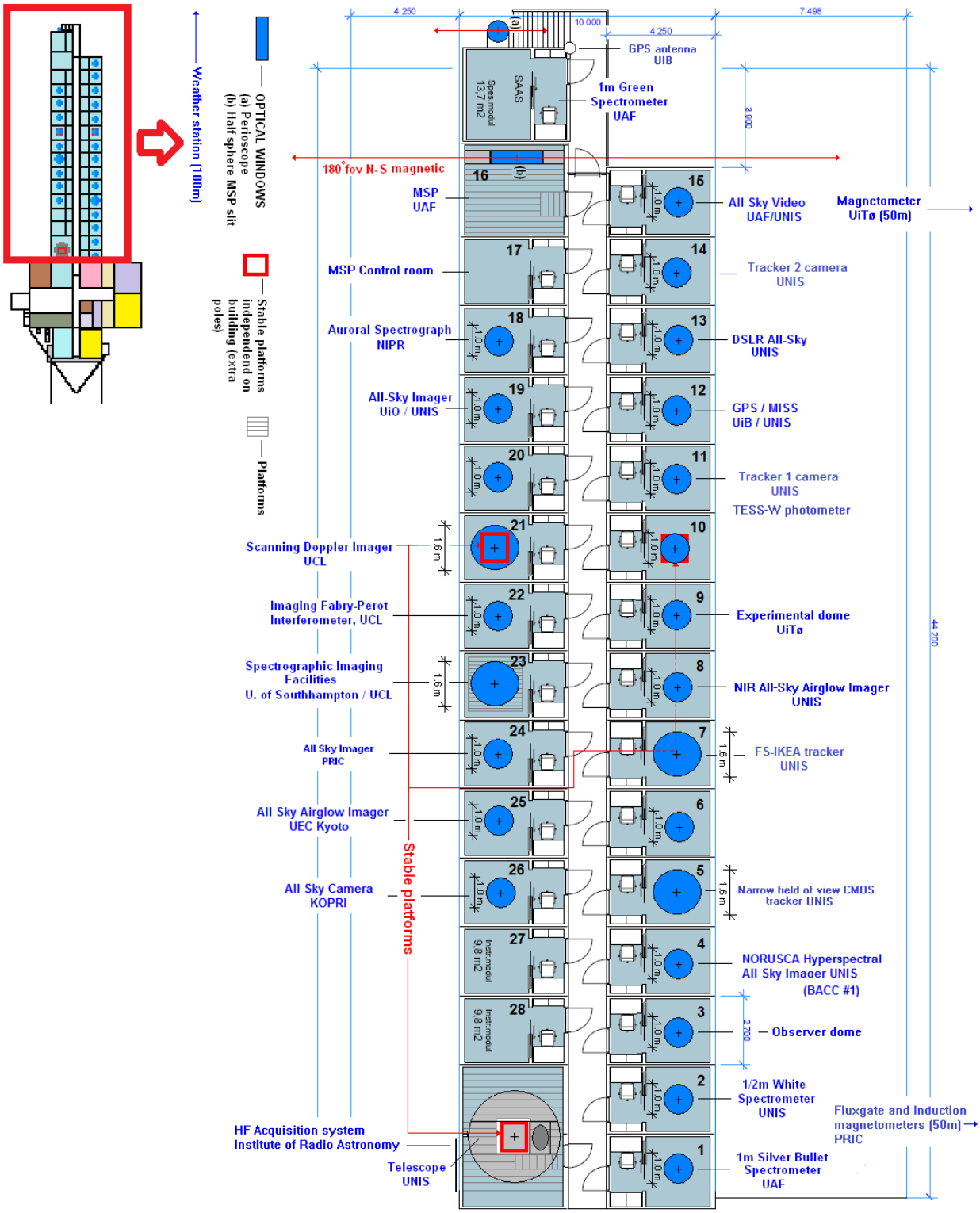


Fig.3. Map of the Instrumental section (I) at the Kjell Henriksen Observatory (2019).

Instrument module 27 and 28 was used as guest domes during the CREX-2 rocket campaign.

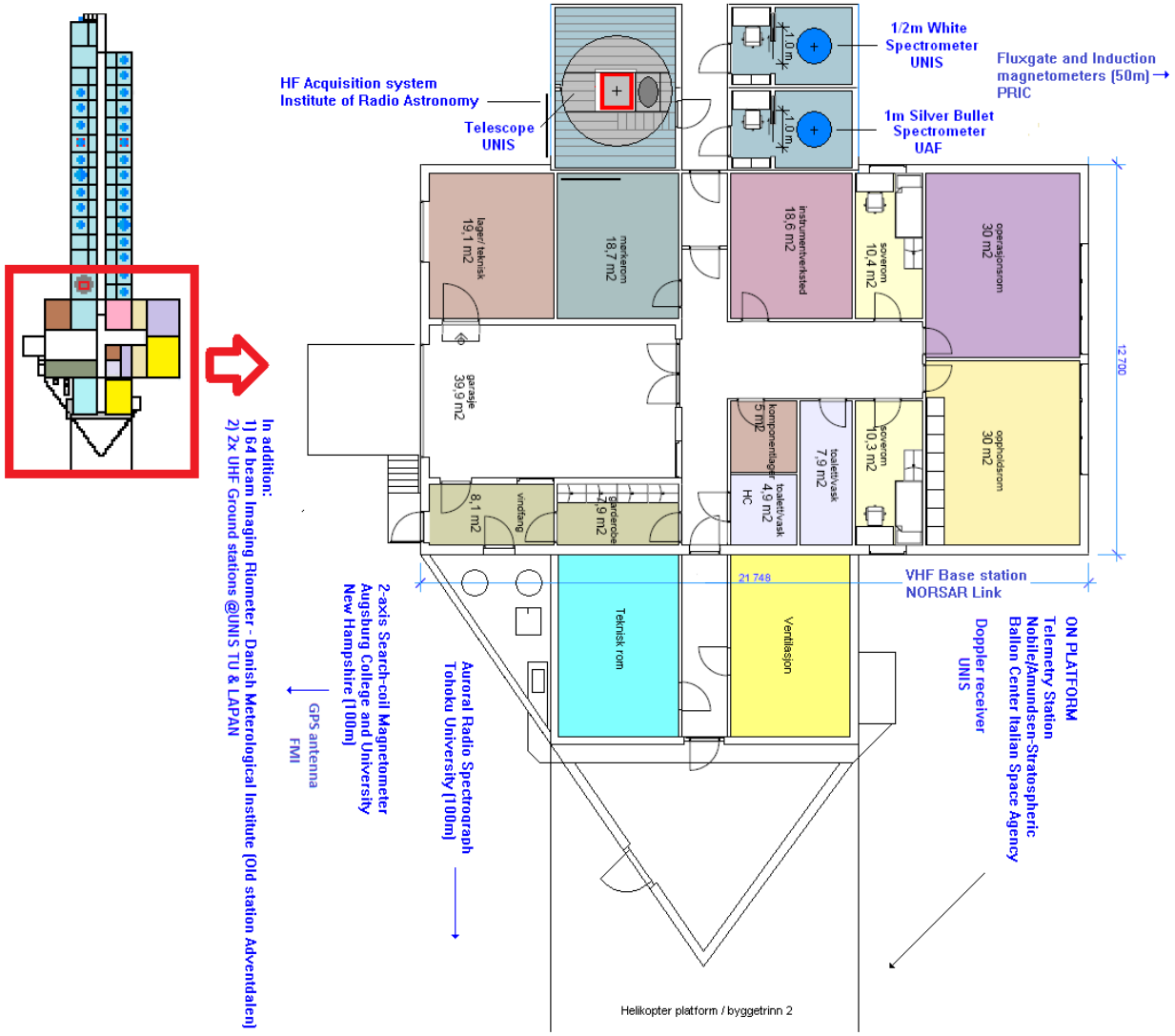


Fig.4. Map of the Service section (II) at the Kjell Henriksen Observatory (2019).

(4) State of the building – Excellent!

The exterior of the observatory has been painted and water leaks from the domes are now fixed. The domes are re-mounted with proper weather proof in-between rings between dome and roof (hatch plate). Icing on the inside of the domes in early December was most probably due to a service hack turning the hot air ventilation automatically OFF during the night to save power. Issues with dirty fresh water tank and pump have also been fixed successfully.

The garage floor was re-painted with ant-slip paint to improve safety at work. There also was a plumbing issue, which was caused by collapsed pipes under the building that eventually froze. The support structures have to be reinforced in summer 2020.

One minor item remains to be investigated. Electrical noise is believed to be generated by the gas-discharge light tubes in the hallway of the instrumental section. The Silver bullet spectrometer detects large spike count noise patterns when they are in use - even with the detector high voltage turned OFF.

(5) Major Highlights – News events

CAPER-2 rocket launched! January 4, 2019

Today at 09:26:58 UT the Cusp Alfven and Plasma Electrodynamics Rocket-2 (CAPER-2) was launched from Andøya over Svalbard into perfect optical cusp conditions as seen from KHO. ASC: **Info** NORUSCA camera: **Movie** Data Screen dumps: [**1**, **2**, **3**, **4**, **5**, **6**, **7**, **8**, **9**, **10**, **11**, **12**]

U.S. Ambassador to Norway April 1, 2019

We are proud to announce that the U.S. Ambassador to Norway and former Rear Admiral United States Navy Kenneth J. Braithwaite has visited KHO. He was informed about our long standing relation and excellent co-operation with U.S. space science. More info **here**.

Exceptional image! April 11, 2019

The CAPER-2 rocket launch was captured by pilot Eivind Trondsen on the Lufttransport Dornier 228 flight from Ny-Ålesund to Longyearbyen. The sun illuminated rocket trail is seen towards the south horizon as the rocket penetrates the upper layers of the atmosphere. More details **here**.

RENU 2 makes headlines April 23, 2019

The GRL overview paper by PI Marc Lessard of the Rocket Experiment for Neutral Upwelling 2 (RENU2) is making headlines in PHYS.ORG. KHO is sited and our BACC camera movie of the dayside aurora is highlighted. Read article **here**.

Minister of Research visits May 4, 2019

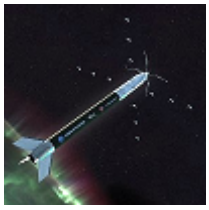
On Saturday morning, our Minister of Science and Higher Education in Norway Iselin Nybø and her crew visited and inspected KHO. To the left the Minister checks out our observational dome in the instrumental section. More images **here**.

Master Marie Bøe Henriksen! June 1, 2019

Congratulation to Master Marie Bøe Henriksen! She has studied our miniaturized Hyper Spectral Imagers (HSI) in detail. Her work is focused on calibration and image correction. She is now a PhD. student at **NTNU AMOS**. Read thesis **here**.

A Shot in the dark November 14, 2019

NASA just released an informative video and audio documentary of the VISIONS-2 (VISualizing Ion Outflow via Neutral atom Sensing-2) rocket campaign. More media events will follow and we are very happy to be part of it! Media : **Youtube**, **Audio**, **Blog**, and **Facebook**



ICI-5 launched! November 26, 2019

Today Prof. J. Moen from UiO/UNIS launched successfully together with the EISCAT Svalbard radar and us the ICI-5 (Ionospheric Cusp Irregularities-5) rocket into the dayside aurora at 07:43:04 UT from **SvalRaK**. The rocket is part of the **GCI** and aims to study how GPS signals are disturbed by aurora. Info **here**. Launch **movie**.

Dutch Trainee December 2, 2019

Together with Eindhoven University of Technology (**TU/e**) we congratulate Charlotte van Hazendonk on her Erasmu+ Traineeship at UNIS. She has in detail characterized our Hyper Spectral Imager (HSI) V6 with focus on radiometric calibration including the gain function. A novel procedure to remove second order spectral effects is also presented. Read report **here**.

CHI launched! December 10, 2019

Left shows as observed from KHO, one out of eight Barium / Strontium high altitude clouds released from the Cusp Heating Investigation (CHI) NASA rocket. It was launched successfully at 09:30 UT from SvalRak. PI of the campaign is Prof. Miguel Larsen from the Clemson University in USA.
More info **here**. Video Clips [**1**, **2**, **3**, **4**, **5**]
Screen dumps: [**1**, **2**, **3**, **4**, **5**, **6**, **7**, **8**, **9**, **10**, **11**, **12**, **13**, **14**, **15**]

Dr. Erkka Petteri Heino! December 18, 2019

We are proud to announce that on Wednesday 18th December 2019 Erkka Petteri Heino successfully defended his PhD thesis titled: Spatial extent of solar proton impact in the Earth's atmosphere - Observations and modeling. Read thesis **here**.

Aurora Seashell! December 24, 2019

Jennifer Briggs, a physics student at Pepperdine University in Malibu, has analyzed our BACC data and discovered a new type of twisted dayside aurora related to an extreme foreshock out in the magnetosphere.
Link NASA **statement**, **Space.com** or **Forbes**

(6) Public outreach

Numerous presentations, visits and interviews have been conducted at KHO. Visits from the local schools in Longyearbyen have also been popular activities. The Aurora Forecast 3D app is rated as 4.28 and has reached over 9147 active installs on Google Play for Android. On Apple iOS phones it is rated 4.4 with 958 active users. The app is believed to be popular mainly in the auroral tourists industry and in the amateur radio community. The Facebook page for KHO has 1475 followers.

(7) 1-2-3-4 - rockets!

KHO has in 2019 actively supported 4 rocket campaigns connected to the Grand Challenge Initiative (GCI). The optimal launch time to study the dayside cusp aurora has been provided to the Primary Investigators (PIs) of the rockets.

The first rocket named CAPER-2 (Cusp Alfven and Plasma Electrodynamics Rocket-2) was launched from Andøya Space Centre (ASC) on 4th of January 2019 by Primary Investigator (PI) James LaBelle from Dartmouth College in USA.

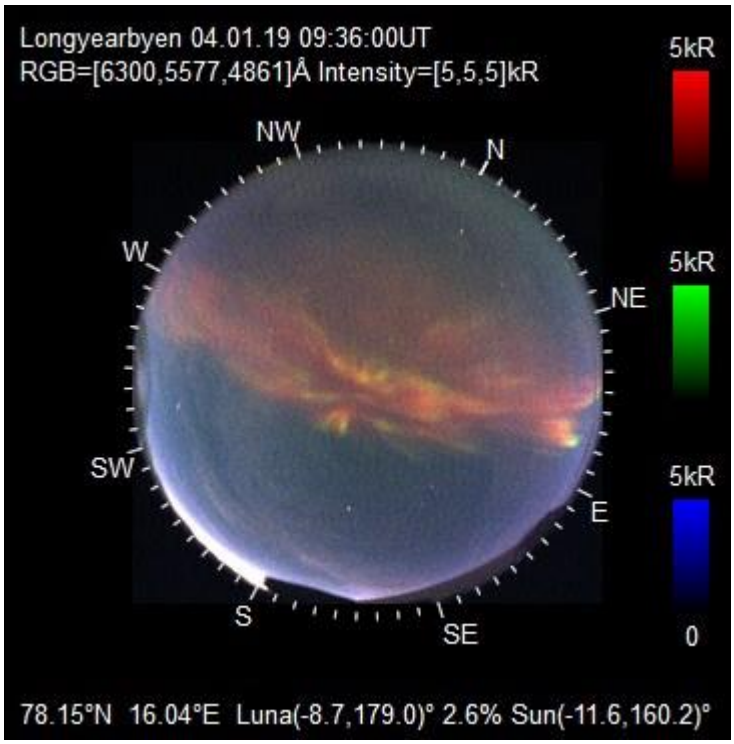


Fig. 5. CAPER-2 target cusp aurora. Composite image by the NORUSCA II hyperspectral camera. See movie here.

Fig. 6. CAPER-2 rocket heading towards Svalbard. Photo by Lufttransport pilot Eivind Trondsen.

The target of the CAPER 2 rocket was the dayside cusp aurora. Figure 5 shows a composite RGB image from the NORUSCA II hyperspectral camera at KHO. The red, green and blue color planes represent the auroral atomic Oxygen [OI] 630 nm, [OI] 557.7 nm and Hydrogen 486.1 nm

emissions. The cusp aurora has intensity up to 5 kR and is predominantly red in color due to low energy electron impact with atomic Oxygen releasing the [OI] 630 nm emission.

The cusp aurora was stable for several hours just north of zenith as seen from KHO. The geomagnetic activity was low at Kp index = 2 with IMF Bz negative. Note that our Aurora Forecast 3D app matched the size and location of the aurora oval as predicted. The rocket was launched from Andøya at 09:27:00 UT with a flight time of only 8 minutes and 49 seconds to apogee at 774.2 km altitude above Svalbard (09:35:49 UT). Total flight time was 957 seconds or splash down at 09:42:57 UT.

The event was also captured by pilot Eivind Trondsen on Lufttransport Dornier 228 flight from Ny-Ålesund to Longyearbyen. See the snapshot in Figure 6. The sun illuminated rocket trail is seen towards the south horizon as the rocket penetrates the upper layers of the atmosphere. These trails may extend high into the mesosphere and thermosphere. High altitude winds may deform, twist and blow them long distances.

During the moon down period from late November to mid-December the geomagnetic activity was low with Kp index less than 3. The cusp is under these conditions located north of Svalbard, out of range for any rocket launched from SvalRak in Ny-Ålesund. This was the conditions in the early morning on 26th of November. But after a 15 minutes negative excursion of the Bz-component of the Interplanetary Magnetic Field (IMF) measured by the NASA Advanced Composition Explorer (ACE) satellite, the activity was expected to expand south with a lead time of about one hour. As predicted, an auroral arc appeared in the zenith of Ny-Ålesund and the second rocket named ICI-5 (Ionospheric Cusp Irregularities-5) was launched at 07:43:04 UT headed by GCI PI Jøran Moen from University of Oslo. The launch decision was a successful quick draw based on multi-site ground-based data support from Ny-Ålesund, KHO and the ESICAT Svalbard radar.

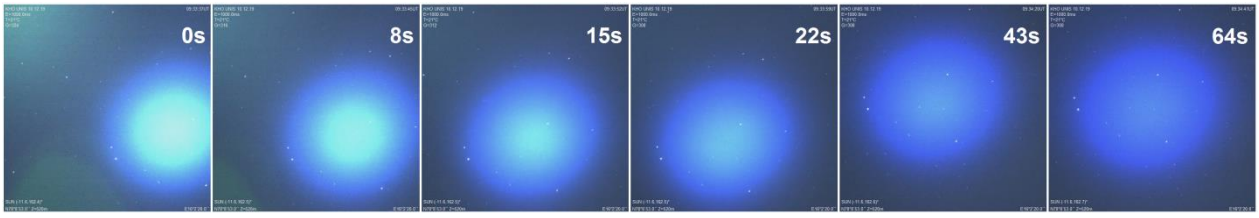


Fig.7. Movie Snapshots from the BACC tracker 2 camera at KHO of a Barium / Strontium cloud released from the CHI rocket launched from Ny-Ålesund 10th of December 2019. Exposure time is 1 second. FOV is 8.2 degrees.

In early December the last two NASA rockets for the season named CHI (Cusp Heating Investigation) and CREX-2 (Cusp Region Experiment-2) were ready to launch from SvalRak and ASC, respectively. PIs of the campaign were Mark Conde (CREX-2) from University of Alaska and Miguel Larsen (CHI) from the Clemson University in USA. These two rockets release Barium, Strontium and Tri-methyl aluminum clouds that when illuminated by the Sun are excellent tracers for the motion of charge particles in the ionosphere and for high altitude

ionospheric winds through neutral particles. The clouds are tracked by ground-based optics from both Ny-Ålesund and KHO. In addition, a NASA King Air aircraft was used to track the artificial clouds from a third observational point above any low altitude cloud layer.

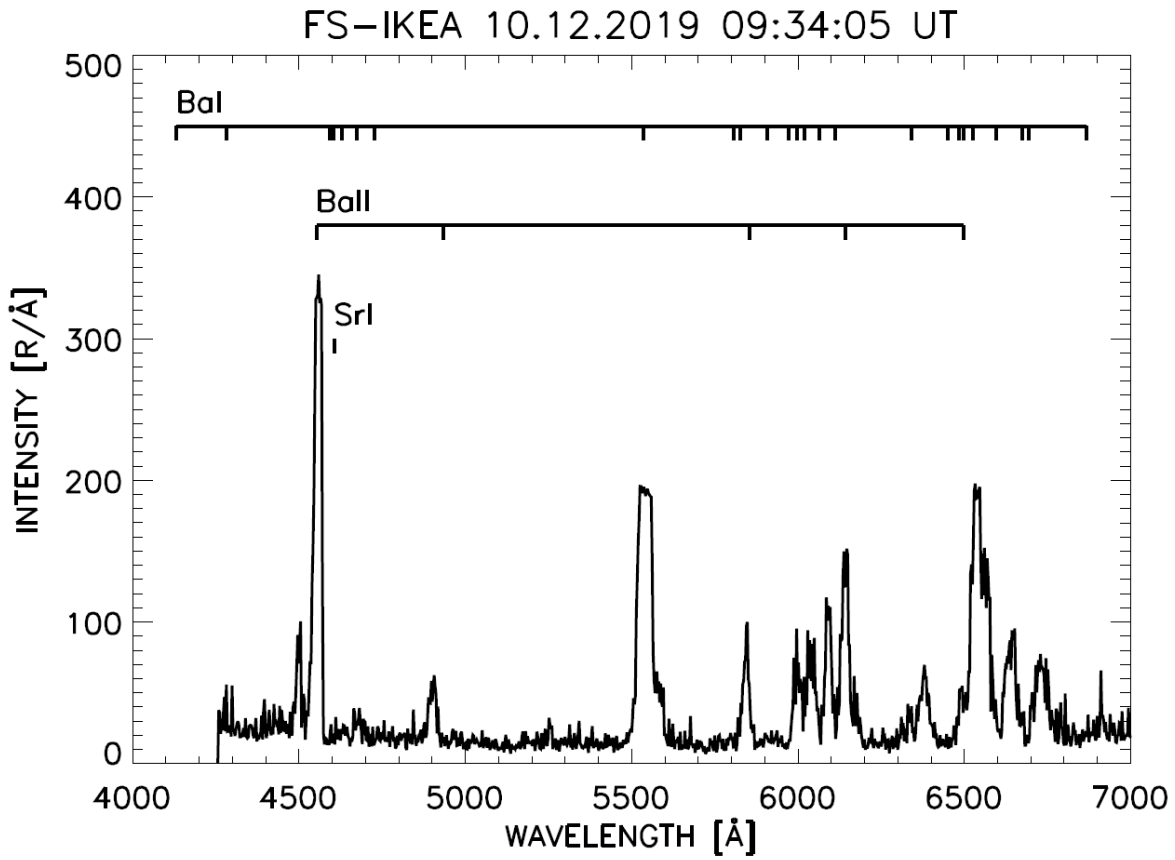


Fig. 8. FS-IKEA spectrum of Barium / Strontium cloud released from the CHI rocket launched from Ny-Ålesund 10th of December 2019. The tracker was pointing 270 degrees azimuth (NW) at 58 degrees elevation. Exposure time was 5 seconds and gain was set to 220.

Both weather and low activity space conditions forced us to wait almost throughout the launch window (26th November - 12th December). The northward located cusp was out of reach for the nominal trajectory of the CREX-2 rocket. But not for CHI and finally, under launch conditions similar to ICI-5, the CHI rocket was launched at 10th of December 09:30 UT. The weather was clear in Ny-Ålesund. A thin layer of clouds moved in and out of the field of view at KHO, but we managed to track the releases as shown in Figures 7 and 8.

Fortunately, a fourth ground based observational point was added to the campaign by Hilde Fålun Strøm and Sunniva Sorby at the trapper's hut named Bamsebu where they served as citizen scientists – Hearts in the Ice - affiliated with the Aurorasaurus project. Doing it old school with a tripod outside, they managed to capture 65 time lapse photos of the event. Unfortunately, CREX-2 was not in a position to launch and is most likely to be rescheduled for 2021.

(8) Instrumental development

One of the key activities at KHO is to develop instruments and seek opportunities as new technology is being developed. Especially, the rapid development in sensors fuels the imagination and creation of designs that does not require moving parts.

The Meridian Imaging Svalbard Spectrograph (MISS) and the Boreal Auroral Camera Constellation (BACC) are now operational and have proven to provide valuable data to several rocket campaigns.

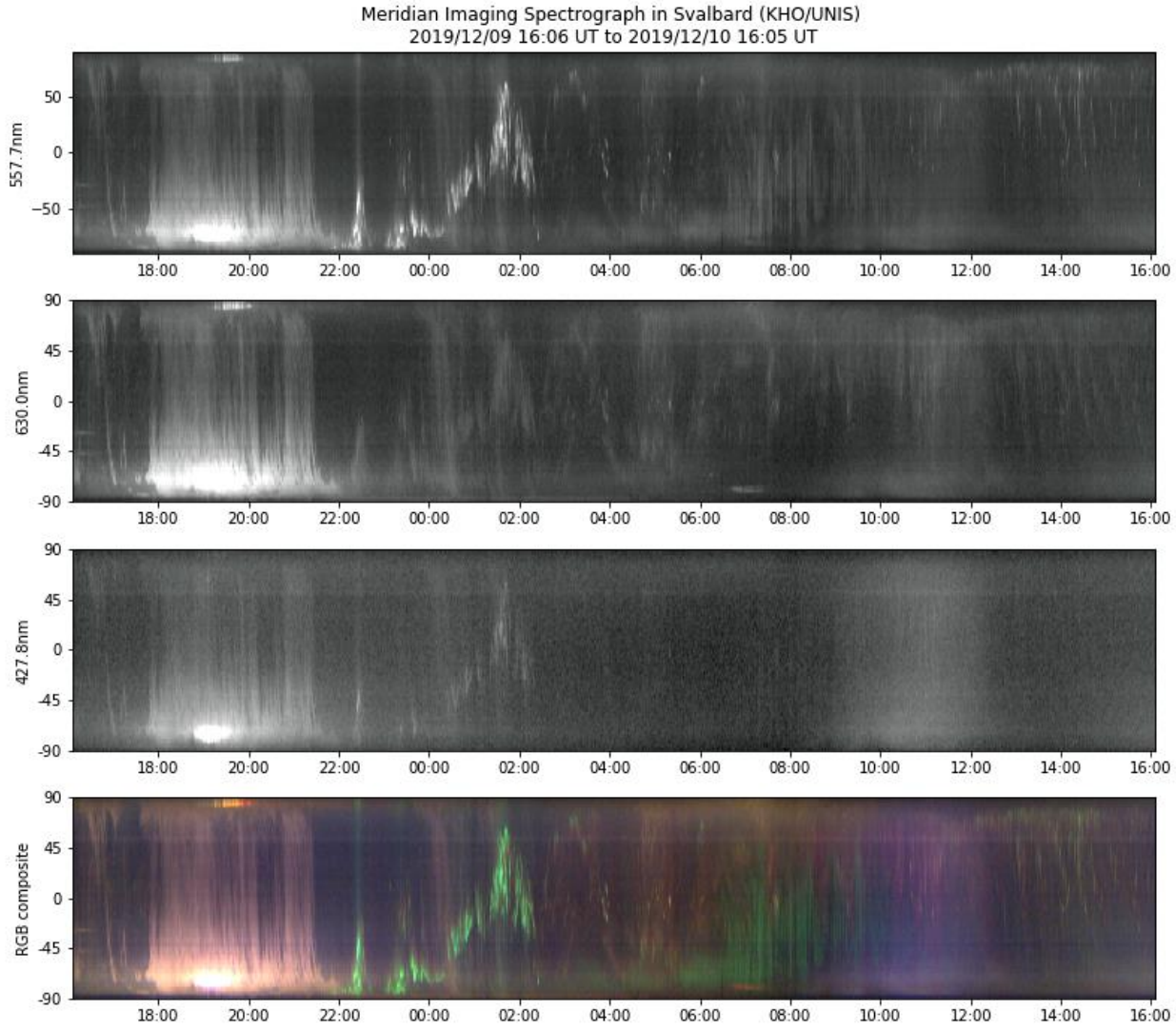


Fig. 9. Meridian Imaging Svalbard Spectrograph (MISS) keograms from 9-10th of December 2019. The top, middle and bottom panels correspond to auroral emission intensities at wavelengths 557.7, 630 and 487.2 nm, respectively. Hemispheric geomagnetic North to South slices of sky intensities is stacked as a function of time to get an overview of auroral activity. Bottom panel is a RGB color composite using the above channels.

The MISS is close to the performance of our old Meridian Scanning Photometers (MSP). We aim to construct a second MISS to be installed in Ny-Ålesund. The estimated cost is ~1M NOK.

SvalPoint - a multi optical pointing system, operated successfully during the CHI rocket campaign. The system has been software upgraded with a command based client tool to control the 4 trackers remotely. The trackers may now be controlled all together by one user or independently by several users. The main problem is to view the data in real time from all of the instruments. The proposed solution is to install a 4 screen computer in the control room. In addition we need to upgrade the control room with new computer and screens. Two extra computers with 4 screens each would solve the problem. A total of 12 new screens to control the instruments and view data from external sources should be a cost effective solution. It is also vital in order to provide rocket PIs the right launch decision criteria.

In cooperation with the Norwegian Centre of Excellence named NTNU AMOS we have successfully, applying our knowledge of spectroscopy, constructed a Hyper Spectral Imager (HSI) that is the core instrument to the satellite named HYPSO (HYPER-SPECTRAL SMALLSAT FOR OCEAN OBSERVATION) that will be launched in 2020. Furthermore, the design of a new HSI for the wavelength region 1000 – 1600 nm has started. One design is based on a Volume Phase Holographic (VPH) grating with an Indium Gallium Arsenide (InGaAs) image detector.

(9) Data policy

The access to data from KHO is open with quick looks and instrumental snapshots in real-time on our web server http://kho.unis.no. Raw data is available on requests to the PI's of the instruments. For example, our decision to make raw all-sky camera data accessible to the student at Pepperdine University in Malibu, under the guidance of Dr. Gerard Fasel, has turned out to be a success. As a result, numerous papers and posters have been presented at the AGU fall meetings in San Fransisco. Only this year, the group managed to present 4 posters and submitted 2 papers based on our data.

All data from KHO are archived to the Norwegian e-infrastructure for Research and Education for long-term storage.

(10) General strategy statement

The main purpose of KHO is to study processes in the magnetospheric cusp and how it connects to interactions between the Sun and our atmosphere. The unique location and the multi-disciplinary instrumental infrastructure such as radars and optics enable us to study the whole atmospheric vertical column to obtain a better understanding of space- and planetary weather. A vital key in this concept is to upgrade, develop and compare instruments as novel technology and knowledge emerge. Therefore, the aim is to strengthen the co-operation with our existing groups and invite new ones. We wish to be upfront as an attractive partner to large scale rocket and satellite campaigns both on the instrumental and observational side.

NOTE

The internal research funding of UNIS is of vital importance in future plans. It enables us to preserve the instrumental momentum and helps us keep track of new technology as it arrives. It seeds our research plans and proposals and is as a consequence strategically important to us. This must not be underestimated compared to our external funding which is more tied up or locked to predefined proposal tasks.

(11) Future threats

It is time to identify after more than a decade of operation what are the future threats to KHO. The immediate threat for our operation is the growing number of dog yards by the foot of the mountain into the Bolterdalen valley. When driving from Longyearbyen into Adventdalen the illumination from these yards look like a small city. This was not the case when we built KHO back in 2008. Numerous attempts through Svalbardposten to encourage to at least turn OFF lights when they are not in use have failed. Dialog is not working even though we have a political consensus from the local government that light pollution should be kept to a minimum. It is time to propose harder measures such as increasing the electrical bill for these activities. An action plan is needed or KHO will have to move if the situation continues. It is a paradox that the tourist industry does not seem to understand the value of dark skies and aurora.

The second long term threat is the lifetime of Mine 7, which is expected to operate for a maximum of 20 more years. There are several scenarios that should be evaluated and discussed. If we stay co- located with the EISCAT Svalbard radar, the access to the mountain keeping the road up the mountain open all year, will most probably double or triple the operational costs. If we have to move due to light pollution, then we will need a new road and infrastructure further away from Longyearbyen and Bolterdalen. One alternative could be to move deep into Adventdalen. Note that this is not compatible with the environmental plan to make inner Adventdalen a conservation area. Our concerns should be taken seriously in order to secure our mandate from the Norwegian Parliament to operate an auroral observatory and respect the taxpayer's contribution.

(12) Future possibilities?

Two more GCI rockets are on the launch pad. The CREX-2 and the Japanese SS-520 will be launched with KHO support. Our instruments are tuned and we are ready. But what do we see developing on a longer timescale?

It is hard to look into the crystal ball to predict the future. It might be possible to see where we are heading by first looking into the past. Back in the 80's at the old station in Adventdalen, the main focus was to map the dayside auroral oval. Spectral measurements from this period are crucial to our understanding of the dayside aurora with the quantization of the red to green ratio being high. Or in other words, the dayside aurora is red because it is caused by soft

electron precipitation. In parallel, measured spectral Doppler profiles of the hydrogen lines, revealed low energetic proton precipitation. These signatures together with how the auroral arcs move across our field of view are directly related to magnetic reconnection out in the dayside magnetosphere with associated flux transfer events.

Our spectral measurements of the mesospheric airglow winter temperature are the longest record in the world. Here we early on saw how tides and gravity waves propagate and force temperature fluctuations like waves breaking on a beach at 90 km altitude. Focus later on turned to try to understand trends. Questions like why do we not see a decrease in the arctic mesospheric winter temperature as the Russians have measured further south of us? Our temperature trend calculation is now close to statistical significant, and we have not answered that question yet. It will require time and continuous measurements in the years to come by our legendary Silver Bullet spectrometer.

Throughout the 90's several rockets have been launched into the dayside aurora in order to try to understand why ions are blowing out of the dayside cleft? Now it even turns out that even neutrals are blowing upwards. The big question is why? Or why are our satellites slowed down by a storm blowing upward into space? The more we study the dayside aurora, the more questions needs answer. One thing is certain, we have to continue! Some day we might be able to understand the main processes that control the world's weather machine from space to ground level.

These questions are the driving force of KHO. But how do we proceed in order to answer them? One solution might be to develop long range drones that monitor the aurora above the cloud layer – our old enemy. We could for example fly from Alaska to Longyearbyen with a mobile observatory. This way we would have plenty of time to study fine detailed auroral structures as we then fly slow compared to a high speed satellite. Our community is one of the few in the world that actually could pull something like this off. The aurora community has in the spirit of Kjell Henriksen, no national or political agenda. We are only stopped by our own lack of imagination.

One very real opportunity is to use the open access possibilities to archived data at the Norwegian e-infrastructure for Research and Education. It may not be practical or desirable to allow free access to all raw data as most instruments need proper calibration procedures. However, access to summary plots and possibly colour all-sky images, which often provide the important context for other instruments, should be considered.

(13) Summary

The Kjell Henriksen Observatory (KHO) is part of The Birkeland Centre for Space Science (BCSS) and the activity has been high in 2019 with several events. The observatory hosted two high profile visits by the Minister of Research and the US ambassador to Norway. Preparations for the auroral season were hectic with painting, fixing water leaks from the domes and water supply maintenance. KHO is still attractive to the space science community with 24 external groups from 14 nations present. Our tracking system with 4 cameras is operational and tested successfully. Three rockets have been launched as part of the Grand Challenge Initiative (GCI) with vital ground-based support from KHO. The major highlight was Erkka Petteri Heino's defense in December.

Graduated students

1. Erkka Petteri Heino**,** PhD**,** Spatial extent of solar proton impact in the Earth's atmosphere - Observations and modeling, University of Tromsø, Norway, December 18, 2019.
2. Marie Bøe Henriksen, Master, Hyperspectral Imager Calibration Characterisation and Image Correction, Department of Engineering Cybernetics, Norwegian University of Science and Technology, May 2019.
3. Charlotte Maartje Van Hazendonk, Erasmus+ Trainee, Calibration of a Hyper Spectral Imager, Eindhoven University of Technology, Netherland, August - December 2019.
4. Sara Gasparini, Master, Statistical properties of backscatter from the Longyearbyen SuperDARN radar, Department of Physics, Norwegian University of Science and Technology, August 2019.
5. Rikke Hedelund Hansen, Master, A Comparison of Naturally Enhanced Ion Acoustic Lines and Auroral Spectral Line Emissions, Department of Physics and Technology, The Arctic University of Norway, June 2019.
6. Florine Enengl, Master, On the relationship between energetic electron precipitation and mesopause temperature, KTH Royal Institute of Technology, May 2019.
7. Joshua Dreyer, Master, A detailed study of auroral fragments, Uppsala University, June 2019.

Presentations 2019

1. Marie Bøe Henriksen, Joseph Landon Garrett, Elizabeth Frances Prentice, Fred Sigernes, Annette Stahl and Tor Arne Johansen, Real-time Corrections For A Low-cost Hyperspectral Instrument, 10th Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS), 24-26 September, Amsterdam, Netherlands, 2019.

2. F. Sigernes, M. B. Henriksen, M. Syrjäsuo, T. A. Johansen (invited): Hyper Spectral Imager for Drones and micro Satellites, 19th International EISCAT Symposium and 46th Annual European Meeting on Atmospheric Studies by Optical Methods ,19 – 23 August, Oulu, Finland, 2019.
3. Bland, E. C., Partamies, N. and Heino, E. (poster), Energetic particle precipitation occurrence rates determined using the Super Dual Auroral Radar Network, EGU Spring Meeting, Vienna, April 2019.
4. Bland, E. C., EEP occurrence rates and pulsating aurora spatial extents determined using SuperDARN radars, CHAMOS Workshop 2019, Helsinki, Finland, 8-11 October 2019.
5. Fasil Tesema, Noora Partamies, Hilde N. Tyssøy: Particle precipitation energy spectrum during pulsating aurora, 19th International EISCAT Symposium and 46th Annual European Meeting on Atmospheric Studies by Optical Methods 19-23 August, Oulu, Finland, 2019.
6. E. Heino and N. Partamies. Riometer Observations and Modelling of Cutoff Latitudes During Solar Proton Events, The 27th IUGG General Assembly, Montreal, Canada, 2019.
7. E. Heino. EPP effects on the neutral atmosphere and the climate, Presentation for the Norwegian Ministry of Defence and foreign military attaches in Norway, UNIS, June 2019.
8. G.J. Fasel, J. Briggs, J. Mann, F. Sigernes, and D. Lorentzen, Poleward-moving auroral forms and their connection to the solar wind speed, AGU Fall meeting, 9 – 13 December, San Fransisco, USA, 2019.
9. G.J. Fasel, L.C. Lee, J. Mann, J. Briggs, K. Butler, F. Sigernes, and D. Lorentzen, East-West Brightening in Poleward-Moving Auroral Forms and the Interplanetary Magnetic Field By –Component, AGU Fall meeting, 9 – 13 December, San Fransisco, USA, 2019.
10. K. Butler, G.J. Fasel, J. Briggs, A. Mascot, L. Hickmann, M. Kim, J. Mann A. Merritt, A. Nguyen, A.D. Oneto, S. Zhou, Fred Sigernes, and Dag Lorentzen, Dayside Auroral Oval Shifts Due to Enhanced Solar Wind Dynamic Pressure, AGU Fall meeting, 9 – 13 December, San Fransisco, USA, 2019.
11. Jennifer Briggs, David Sibeck, Marcos Silveira, Gerard Fasel, Sun Hee Lee, Mike Ruohoniemi, John Mann, Fred Sigernes, and Dag Lorentzen, Ionospheric Response to a Transient Event at the Magnetopause, AGU Fall meeting, 9 – 13 December, San Fransisco, USA, 2019.
12. L. M. Bjoland, Y. Ogawa, U.P. Løvhaug, D. Lorentzen, High-latitude electron density depletion regions and their dependence on geomagnetic activity, 19th International EISCAT Symposium and 46th Annual European Meeting on Atmospheric Studies by Optical Methods ,19 – 23 August, Oulu, Finland, 2019.
13. E. Heino, Cutoff models as boundaries of SPE impact area - Future development of SPE forcing, CHAMOS Workshop 2019, Helsinki, Finland, 8-11 October 2019.
14. N. Partamies, E. Bland, C. Hall, T. Masaki, Pulsating aurora precipitation — Ground-based detection, IUGG General Assembly, July 2019, Montreal, Canada.
15. F. Enengl, N. Partamies, N. Ivchenko, On the relationship of energetic particle precipitation and the mesopause temperature, IUGG General Assembly, July 2019, Montreal, Canada.
16. J. Dreyer, N. Partamies, P. Ellingsen, D. Whiter, A detailed study of auroral fragments, 19th International EISCAT Symposium and 46th Annual European Meeting on Atmospheric Studies by Optical Methods, August 2019, Oulu, Finland.

Publications 2019*

1. Lessard, M.R, B. Fritz, B. Sadler, I. Cohen, D. Kenward, N Godbole, J. H. Clemmons, J H. Hecht, K. A. Lynch, M. Harrington, T. M. Roberts, D. Hysell, G. Crowely, F. Sigernes, M. Syrjäsuo, P. Ellingsen, N. Partamies, J. Moen, L. Clausen, K. Oksavik and T. Yeoman, Overview of the Rocket Experiment for Neutral Upwelling Sounding Rocket 2 (RENU2), *Geophys. Res. Lett.*, 46, 2019, https://doi.org/10.1029/2018GL081885
2. Marie Bøe Henriksen, Joseph Landon Garrett, Elizabeth Frances Prentice, Fred Sigernes, Annette Stahl and Tor Arne Johansen, Real-time Corrections For A Low-cost Hyperspectral Instrument, *IEEE,* 2019*,* https://doi.org/10.1109/WHISPERS.2019.8921350
3. Ogawa, Y., Y. Tanaka, A. Kadokura, K. Hosokawa, Y. Ebihara, T. Motoba, B. Gustavsson, U. Brändström, Y. Sato, S. Oyama, T. Raita, F. Sigernes, S. Nozawa, K. Shiokawa, M. Kosch, K. Kauristie, C. Hall, S. Suzuki, Y. Miyoshi, A. Gerrard, H. Miyaoka, and R. Fujii, Development of low-cost multi-wavelength imager system for studies of auroras and airglows, *Polar Science*, 100501, 2019, https://doi.org/10.1016/j.polar.2019.100501
4. Bland, E. C., Partamies, N., Heino, E., Yukimatu, A. S., & Miyaoka, H. (2019). Energetic electron precipitation occurrence rates determined using the Syowa East SuperDARN Radar. Journal of Geophysical Research: Space Physics, 124. https://doi.org/10.1029/2018JA026437
5. Herlingshaw, K., Baddeley, L. J., Oksavik, K., Lorentzen, D. A., & Bland, E. C. (2019). A study of automatically detected flow channels in the polar cap ionosphere. Journal of Geophysical Research: Space Physics, 124, 9430– 9447. https://doi.org/10.1029/2019JA026916
6. E. Heino, P. T. Verronen, A. Kero, N. Kalakoski, and N. Partamies. Cosmic noise absorption during solar proton events in WACCM-D and riometer observations. Journal of Geophysical Research: Space Physics, 124(2):1361–1376, 2019.
7. N. Partamies, K. Bolmgren, E. Heino, N. Ivchenko, J. E. Borovsky, and H. Sundberg. Patch size evolution during pulsating aurora. Journal of Geophysical Research: Space Physics, 124(6):4725–4738, 2019.
8. Kozyreva, O, V. Pilipenko, D. Lorentzen, L. Baddeley, and M. Hartinger, Transient oscillations near the dayside open-closed boundary: evidence of magnetopause surface mode?, https://doi.org/10.1029/2018JA025684, JGR, 2019.
9. Han, D.S., T. Xu, Y. Jin, K. Oksavik, X-C. Chen, J-J. Liu, Q. Zhang, L. Baddeley and K. Herlingshaw, Observational Evidence for Throat Aurora Being Associated With Magnetopause Reconnection, *Geophys. Res. Lett,* (2019), https://doi.org/10.1029/2019GL083593

*Listed presentations and publications do not include all instrumental groups at KHO, only from the KHO crew.