Status and Highlights - 2020

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 2020. The current active personnel of the observatory are presented together with the operational instruments. The activity has been low due to the outbreak of the corona pandemic. Despite the situation, the observatory has been fully operational. Highlights and achievements are listed together with strategy and future assessments.

(1) The observatory crew

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	Researcher, 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 (2020).

The current crew of KHO is listed above. F. Sigernes headed and had the daily operational responsibility together with Mikko Syrjäsuo. Ida Asklund is our contact from the Norwegian Construction and Property Management Department in Longyearbyen who owns the building.

(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.

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

Fig.1. Fieldwork for AGF-301 students. The students studied real-time solar wind data from the Deep Space Climate Observatory (DSOVR) satellite and the predicted successfully the lead time of the aurora. Date is February 19, 2020. Photo by Mikko Syrjäsuo.

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 at KHO in (2020). Strikeouts are due to cancellation related to the COVI-19 pandemic.

A grand total of **35 ECTS** (European Credit Transfer and Accumulation System) have been taught. Three courses were cancelled in the autumn semester of 2020 due to the COVID-19 pandemic.

(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

A detailed description of the performance and the scientific objective of each instrument are found online.

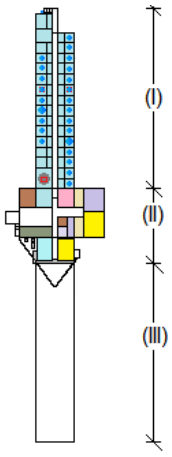

Fig. 2. Sketch of KHO: (I) Instrumental section, (II) Service section, and (III) Extended platform.

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 magnetometers	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 (2020).

Note: 3 new instruments will be installed in 2021. Two from China and one from USA.

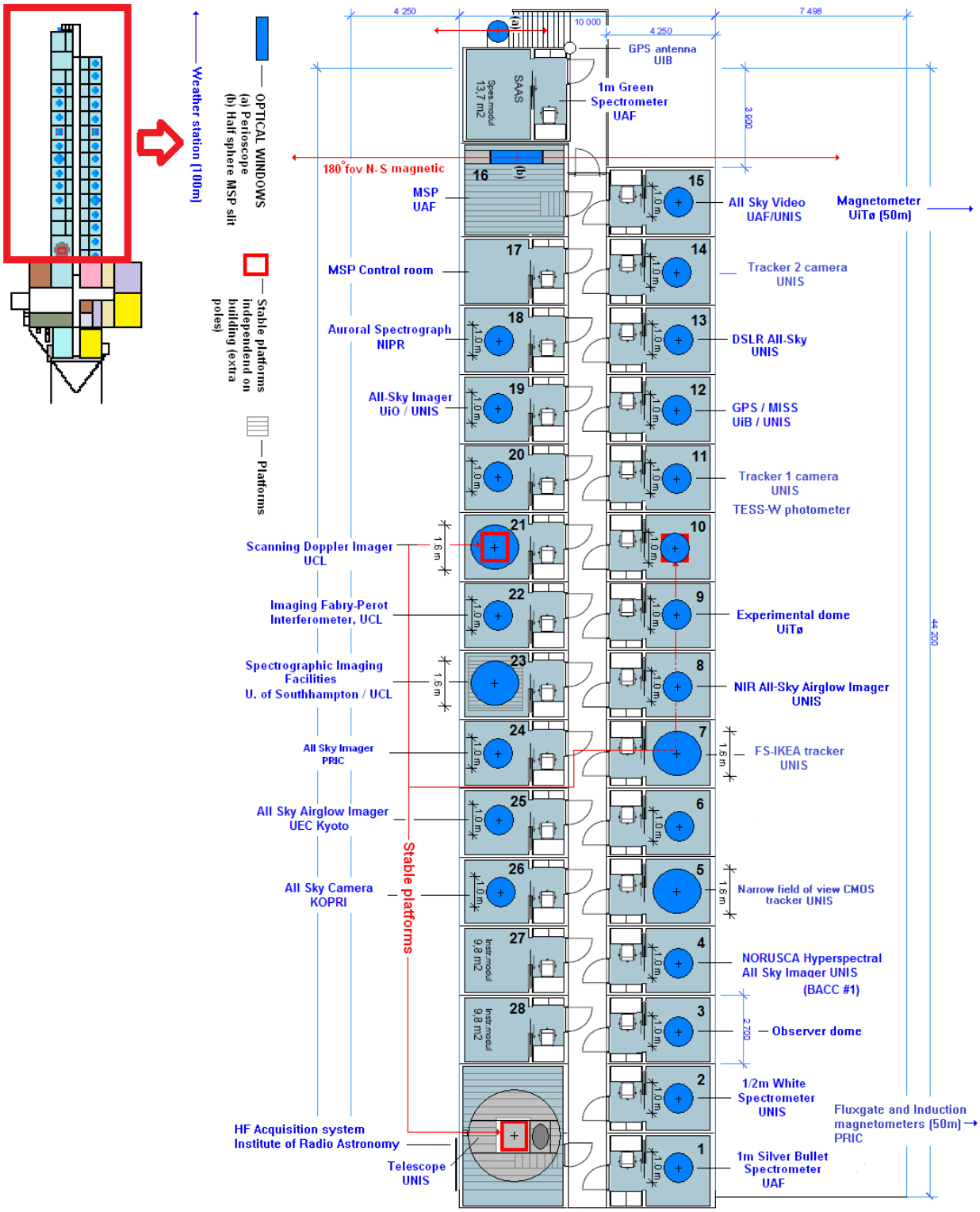

Fig.3. Map of the Instrumental section (I) at the Kjell Henriksen Observatory (2020).

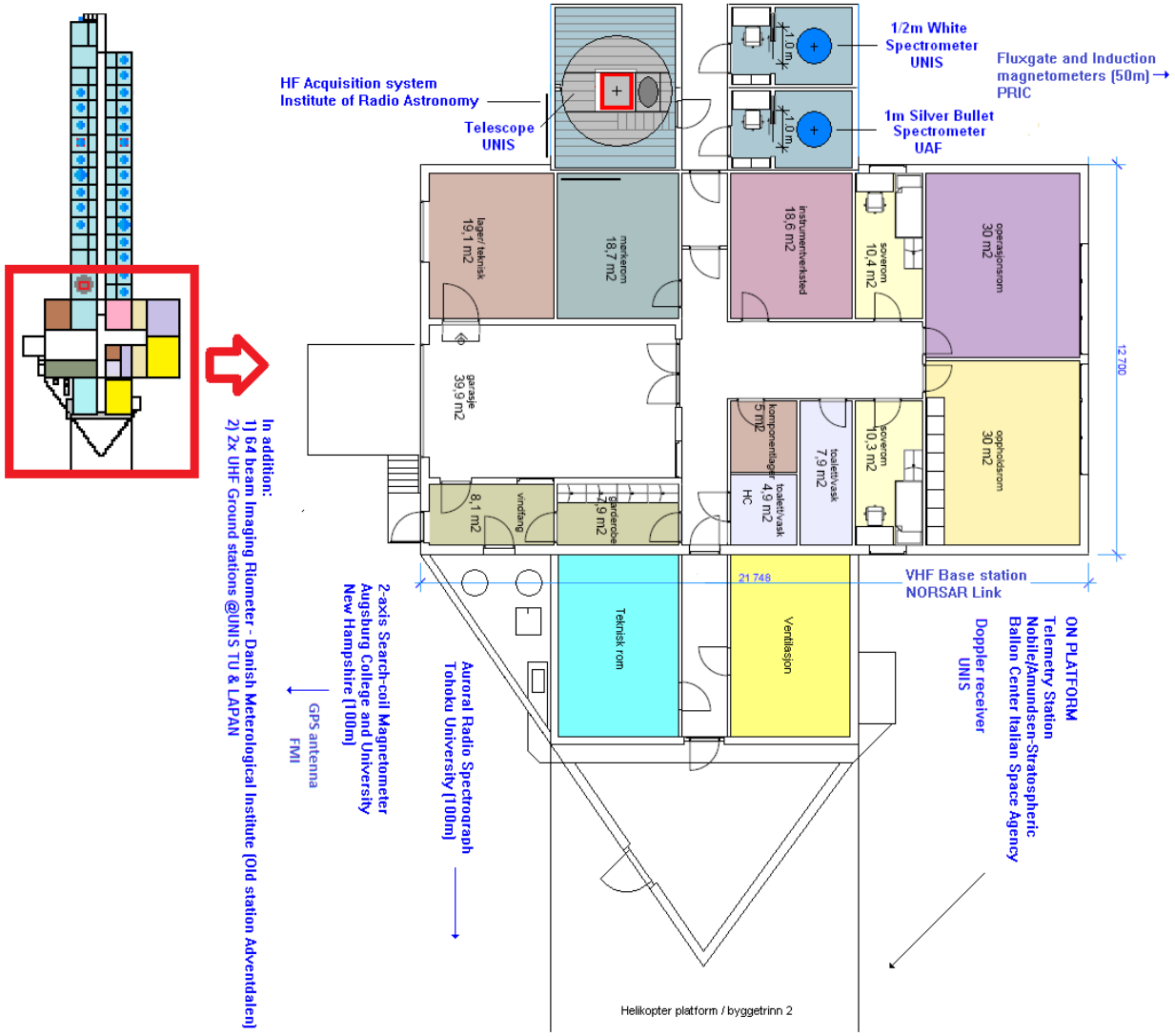

Fig.4. Map of the Service section (II) at the Kjell Henriksen Observatory (2020).

(4) State of the building

After the optical season in late March, a several days long unnotified power cut lead to frozen toilets. It was decided to install new macerator toilets with all tubes and pluming inside observatory to prevent freezing. The sink in the garage is also removed, since it has never been in use. The small entrance port to the water tank room will be blocked by extra outside doors to prevent snow and water penetration. The fresh water supply pump is moved into the tank room to prevent freezing.

All gas-discharge emergency light tubes in the observatory have been replaced by Light Emitting Diodes (LED). The electrical noise generated by the gas-discharge light tubes is thus eliminated. The Silver bullet spectrometer detected large spike count noise patterns when they were in use - even with the detector high voltage turned OFF.

Two urgent item remains to be fixed. The fresh water supply tubes are made of copper and needs to be replaced with stainless steel tubes in order to prevent future erosion and water leaks. This is highly recommended by the chief technician Espen Helgesen at the EISCAT Svalbard radar, where eroded copper pipes caused extensive water damage and total inside renovation and repairs. Secondly, Svalbard Bygg AS has promised to improve their solution to fix leaks between the domes and the roof.

(5) Major Highlights – News events

Master Erlend Salte Kallelid

December 2019

We congratulate Master Erlend Salte Kallelid! He has studied how the ionosphere responds to intense substorms and energetic electron precipitation using data from both magnetometers and riometers. Read thesis **here**.

Snowhow!

January 1, 2020

KHO is part of the TV series named Snowhow that starts on 2nd January 2020. The theme is the Nordic winter and how we cope with it. It is produced by NRK in association with SVT, YLE and NDR.
See NRK link **here**

Linux test release!

May 8, 2020

Our popular Aurora Forecast 3D app is now finally available for testing on Linux platforms. The app is compiled in Windows 10 loaded with Delhi RAD studio 10.3 Architect using FMXLinux onto a 64-bit Ubuntu 18.04.4 LTS Linux computer. Goto download page with instructions **here**.

TU/e Trainee

June 12,2020

Together with Eindhoven University of Technology (TU/e) we congratulate Adrienne Esmeralda Oudijk on her Erasmus+ Traineeship at UNIS. She has used our Hyper Spectral Imager v6 and found how to compress the spectral data cube by a factor of 10^{-4} with minimum loss of spatial resolution and spectral signature. Read report **here**.

Silver Bullet is upgraded!

June 17, 2020

After 40 years of service, the rotary motor system of the Silver Bullet spectrometer died on us. Luckily, it happened at the end of the dark season. A new high precision servo system is now installed.
Read details **here**.

Master Breedveld!

July 2, 2020

Congratulation to Master Mikkel J. Breedveld! He has studied polar orbiting POES / MetOP satellite precipitation data and made new auroral ovals for us. His work will be used in our Aurora Forecast 3D app.
Read thesis **here**.

Mysterious neighbor?

October 24, 2020

To our big surprise a new construction appeared out of nowhere by the road up to the observatory last week. It turned out to be a new vault storing precious American goods for the future. We hope to be invited to the grand opening.
More info **here**.

New aurora forecasts

October 29, 2020

We are happy to announce that release version 6.8 of our Aurora Forecast 3D app now includes two new models of the aurora ovals. Both models are based on years of polar orbiting satellite data from NASA.
More info **here**.

Interactive app

December 10, 2020

Version 6.9 of the Aurora Forecast 3D app now includes detailed target identification. Star constellation, planet, satellite and location information are linked to the Web. The main purpose is to create an interactive learning experience.
Computer downloads **here**.

BACC #5 operational!

December 18, 2020

We are very happy to welcome the Tromsø Geophysical Observatory (TGO) at UiT The Arctic University of Norway to join the Boreal Aurora Camera Constellation (**BACC**) with camera number 5. It is installed and on-line today at the old Skibotn Observatory.
View quick look **here**.

Master Lidia Luque!

December 2020

Congratulation to Master Lidia Luque! She investigated ionospheric signatures of energy input and turbulence in the polar ionosphere using the spectral width parameter measured by the SuperDARN radar (which been used as a proxy for ionospheric turbulence). Lidia examined specific cases of high spectral width and linked them to signatures of energy input into the polar ionosphere using the EISCAT radar and KHO optics. Read thesis here.

(6) Public outreach

Numerous presentations, visits and interviews have been conducted at KHO over the years. Visits from the local schools in Longyearbyen have also been popular activities. Unfortunately, due to the pandemic the observatory has been closed to visitors since March. One highlight was that Girls and Technology (J&T) visited KHO in September. The Aurora Forecast 3D app is rated as 4.4 and has reached over 9470 active installs on Google Play for Android. On Apple iOS phones it is rated 4.4 with 396 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 1516 followers.

(7) Upgrades

After 40 years of operation the Silver Bullet 1m Ebert-Fastie motor system developed a fault last February. Data from this instrument is of high importance since it serves us a mesospheric temperature record dating back to the 80's. A new motor system was installed by the end of June. It is based on a servo motor instead of the old stepper motor design.

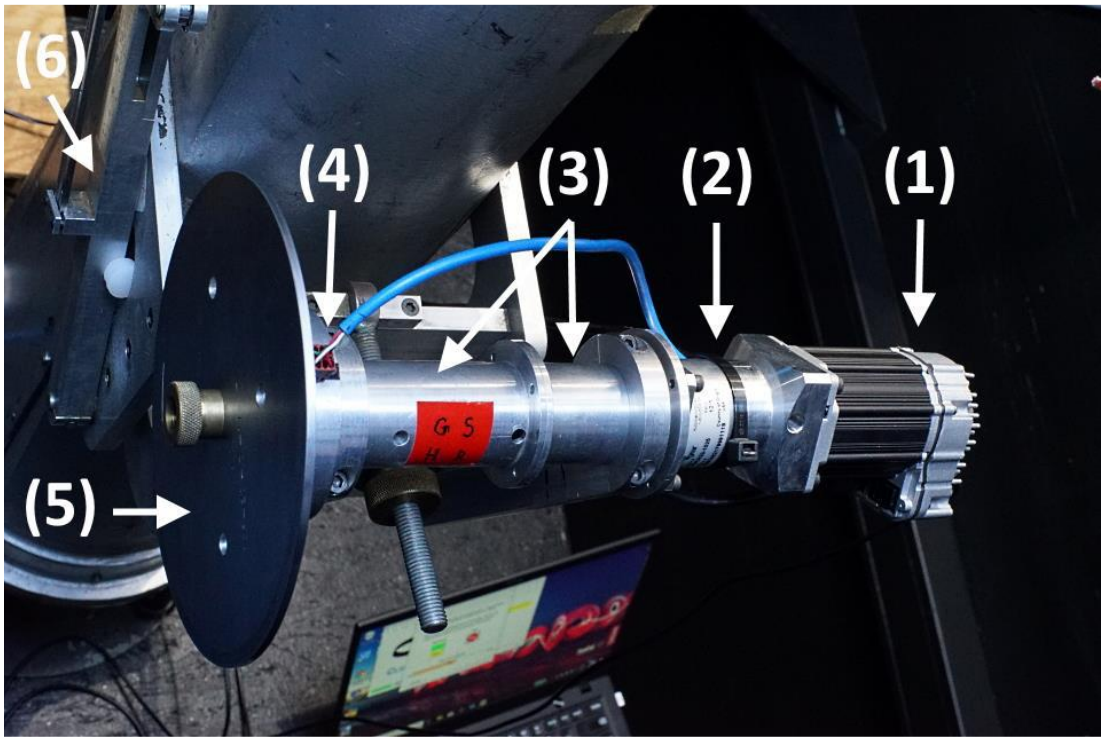

Fig. 5. Upgraded Silver bullet grating cam motor system: (1) servo motor, (2) gearbox – speed reducer, (3) extended motor shaft housings, (4) fiducial sensor, (5) sinusoidal-shaped rotary cam, and (6) intermediate grating arm with moveable pivot.

Fig. 5 shows the upgraded motor system. The grating sweep mechanism is variable in position, amplitude and speed. The position of the sweep is determined by the angular position of the grating arm with respect to the grating shaft. The magnitude of the sweep amplitude (spectral range) is varied by an intermediate arm which has a follower and a moveable pivot on which the grating arm rides.

The new motor is an integrated servo motor with built in encoder and controller. The motor shaft of the servo is directly connected to a planetary gearbox with a 10:1 ratio. With this setup, a 25 RPM motor speed gives a precise cam rotation period of 24 seconds.

The system was tested in early November. The signal from the photomultiplier tubes turned out to be noisy. The noise was by mid-December located to be associated with the power supply of the photomultiplier cooler. After installing a 110 VAC transformer as power source to the cooler supply, the noise disappeared. We therefore suspect that the cooler power supply needs to be checked for noisy components such as old tried out capacitors.

(8) Instrumental development

The Tromsø Geophysical Observatory (TGO) at UiT The Arctic University of Norway joined the Boreal Aurora Camera Constellation (BACC) with camera number 5 in December. It is installed at the old Skibotn Observatory.

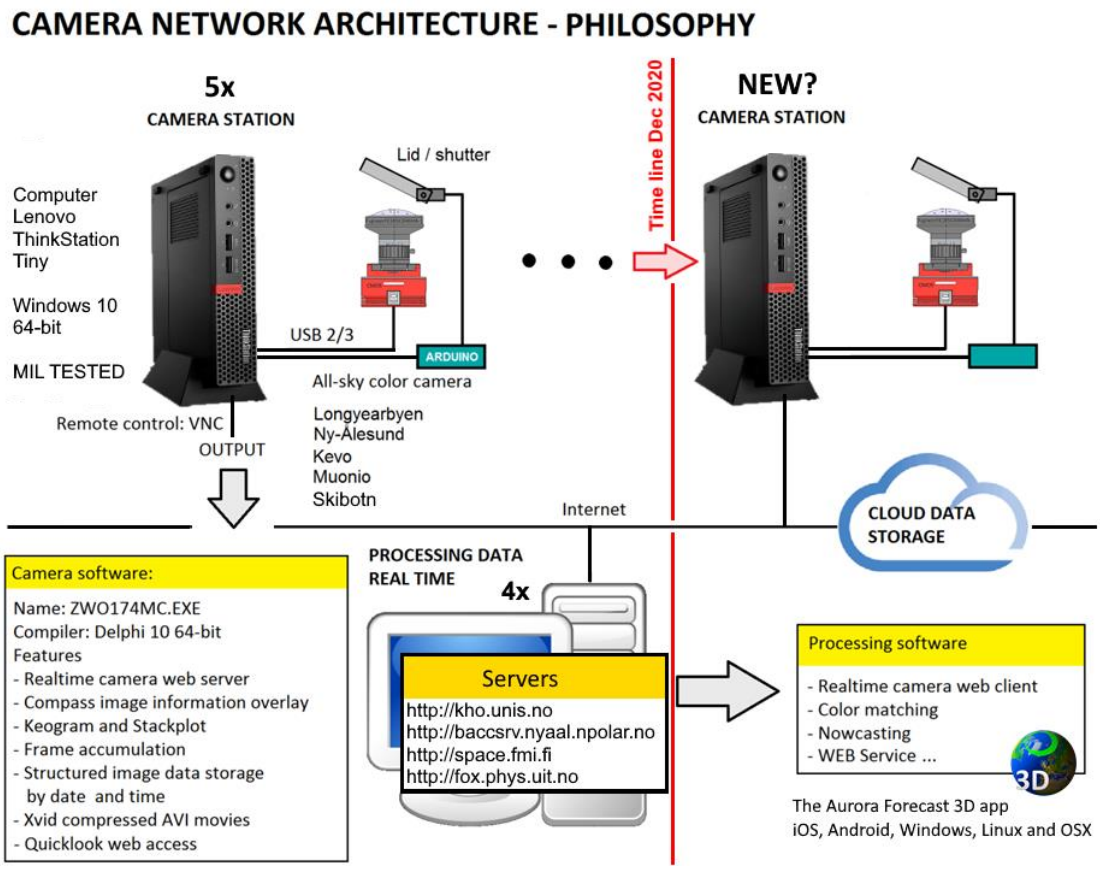

Fig. 6. Sketch of the Boreal Auroral Camera Constellation (BACC).

Fig. 6 summarized the architecture and the main idea behind the camera constellation. Much of the instrumental work in this proposal is already conducted. The main idea behind this project is to expand the network by deploying identical camera stations to multiple sites in the boreal zone.

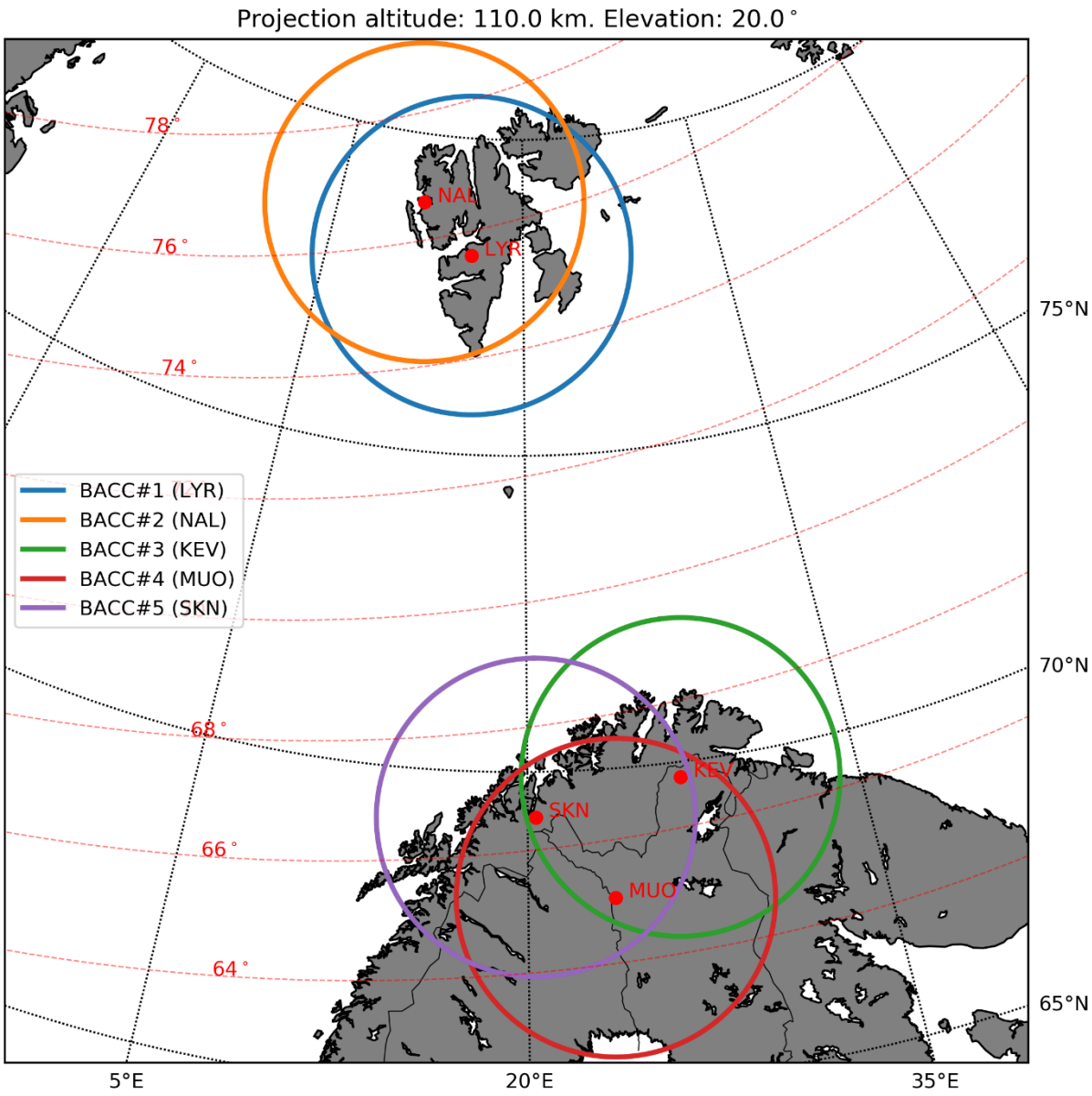

Fig. 7. Estimated Boreal Aurora Camera Constellation (BACC) field of view for 110 km peak emission altitude and blocking set to 20 degrees above the horizon. Camera station abbreviations: LYR – Longyearbyen, NAL – Ny-Ålesund, KEV – Kevo, MUO – Muonio and SKN – Skibotn

Fig. 7 shows the calculated all-sky field of view of the constellation assuming the aurora is located at peak emission altitude 110 km and 20 degree above the horizon. Skibotn is an excellent site for auroral observations due to high frequency of clear skies. Second day after installation on 19th of December 2020, clear sky conditions with sub storm aurora occurred over the Skibotn Observatory.

A movie snapshot of a typical post-midnight structured aurora associated with a sub storm is shown in Fig. 8. Stars and constellations are easily identified by color and magnitude. In fact, the

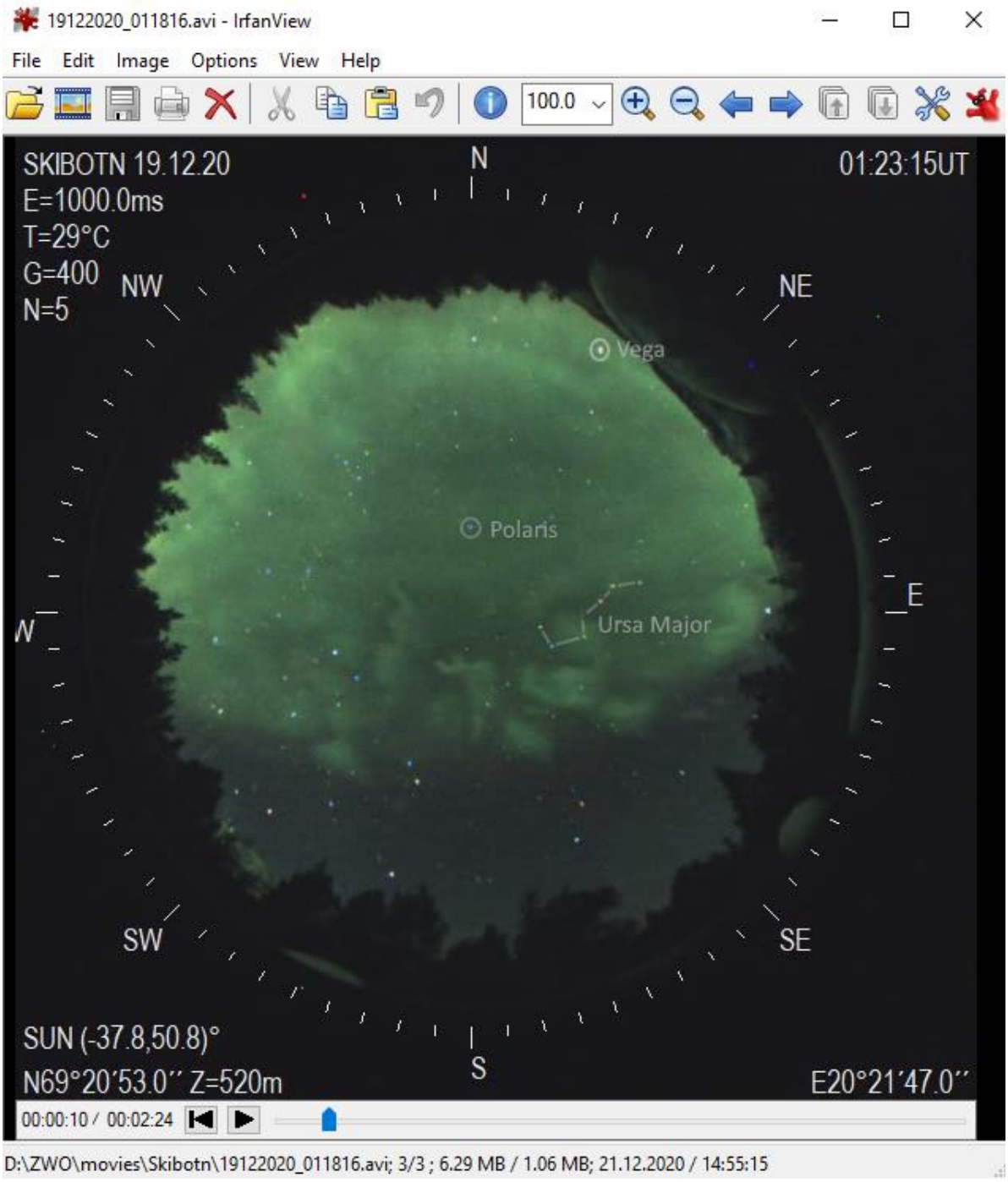

Fig. 8. BACC #5 All-sky color camera movie snapshot from the Skibotn Observatory (SKN) on 19th of December 2020. Typical post-midnight structured aurora related to night side sub storm.

radial mapping function of the lens can be calculated directly from the snapshot. Also note that the light pollution at Skibotn is extremely low.

The current constellation is located to cover Svalbard and northern Scandinavia. The Muonio, Kevo and Skibotn cameras are perfectly located to cover any sky events for the new Eiscat 3D

radar. An old dream to install cameras at Bjørnøya, Hopen or even Jan Mayen could be considered if we can find partners that have a genuine interest to join BACC. An expansion to the East would most likely require a co-operation with the Polar Geophysical Institute (PGI) in Murmansk. But all alternatives need to provide a fast internet connection in order to join the constellation's real-time operational philosophy. To the West, and obvious candidate could be Andøya Space (AS). As seen in Fig. 7, it would increase our field of view to the West to approximately 9°E longitude. In addition, all mainland stations field of view will still be overlapping Skibotn. Future expansion to our colleagues in Iceland, Greenland, Canada and Alaska could also be considered.

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 2021. The program has been delayed due to the COVID-19 pandemic.

(9) Data policy and access

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. Data from KHO are archived to the Norwegian e-infrastructure for Research and Education, UNINETT Sigma 2, using the project *Svalbard Space Physics Storage* for long-term storage.

(10) Data security?

The transfer of data between our servers and clients should be encrypted to increase data security. HTTPS should be enabled to avoid clear text communication. Both Google and Apple have started to insist on TLS/SSL encryption for their apps, which directly affects any further updates and development of our Aurora Forecast 3D app. It also applies to secure communication during rocket campaigns. This matter should be of high of priority to the UNIS.NO domain and UNINETT?

(11) General strategy statement – written in stone

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.

Vital importance

The internal research funding of UNIS is of vital importance in the future. 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 therefore 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.

(12) Future threats

The threats to KHO remain unchanged as identified in last year report. As already reported, 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 was expected to operate for a maximum of 19 more years. The Norwegian Government decided 11th of January 2020 that a new power plant for Longyearbyen with low CO_2 emissions should outsource the current one which is fueled by coal. If SNSK as a result decide to close Mine 7 sooner than originally planned, which is highly likely as stated by the SNSK director Jan Morten Ertsaas in Svalbardposten , then there are several scenarios that should be evaluated and discussed up front. One immediate question arises: who will fund and maintain the road up to the observatory? The situation has become uncertain and forces us to think on how to adapt to the new state of affairs and politics to secure KHO.

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 must 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.

(13) A scientific look into the crystal ball?

Two more GCI rockets are still on the launch pad. The CREX-2 and the Japanese SS-520 will be launched with KHO support. They are both delayed due to the COVID-19 pandemic. Our instruments are tuned, and we are ready. But what do we see developing on a longer scientific 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 statistically 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 must 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 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.

(14) Summary

The activity at the Kjell Henriksen Observatory (KHO) has been low after the outbreak of the corona pandemic. No rocket campaigns have been carried out and no visits from our instrumental partners have occurred. On the other hand, the situation has given us more time to focus on upgrades, instrumental work and new constellations. The observatory has been fully operative since the start of the optical season in November. Contact with our students has been through Teams or Zoom. Despite COVID-19, they all managed to finish their courses and degrees successfully.

Graduated students

1. *Erlend Kallelid*, Master, Evolution in Cosmic Noise Absorption during Periodic Events, NTNU/UNIS. Super*visors:* Patrick Espy (NTNU) and Noora Partamies (UNIS) **–** December 2019.
2. *Adrienne Esmeralda Oudijk*, Erasmus+ Trainee, Hyperspectral Data Cube Compression Techniques and Quality Assessments, Eindhoven University of Technology Netherland (Tu/e)/UNIS. Supervisors: Fred Sigernes (UNIS) and Hjalmar Mulders (Tu/e) – June 2020.
3. *Mikkel J. Breedveld*, Master, Predicting the Auroral Oval Boundaries by Means of Polar Operational Environmental Satellite Particle Precipitation Data, Department of Physics and Technology, Faculty of Science and Technology, UiT - The Arctic University of Norway/UNIS. Supervisors: Fred Sigernes (UNIS), Magnar G. Johnsen (UiT) and Finn Søraas (BSCC) – July 2020.
4. *Lidia Luque*, Master, Multi-Instrument Investigation of Spectral width on the Polar Ionosphere, UNIS / NTNU. Supervisors: Lisa Baddeley (UNIS) and Patrick Espy (NTNU) – December 2020.

Presentations 2020

1. Partamies, Bland, Tesema, Verronen & Kero: Characterization and atmospheric impact of pulsating aurora, invited talk, AGU fall meeting 2020.
2. Nina Kristine Eriksen, Lindis Bjoland, Erkka Heino and Mikko Syrjäsuo, UNIS and Space physics research on Svalbard, Girls and Technology (J&T) visit to KHO, September 2020.

Publications 2020*

1. 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, Vol. 23, 2020, https://doi.org/10.1016/j.polar.2019.100501
2. Jennifer Briggs, Gerard Fasel, Marcos Silveira, David Sibeck, Yu Lin, and Fred Sigernes, Solar-Terrestrial Interactions: Dayside Auroral Observation Resulting from a Rapid

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