annual report 2020

thunderstorms
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blue jets
smile project
asymmetric geos
particle precipitation
ezie satellite

BIRKELAND CENTRE
FOR SPACE SCIENCE

CONTENTS

OUR MISSION

The Birkeland Centre for Space Science (BCSS) was established in March 2013. It is led from the Department of Physics and Technology at the University of Bergen, with nodes at NTNU and UNIS. The overarching scientific objective of the BCSS is to understand "How the Earth is coupled to space." BCSS is organized into three research groups:

- **Dynamics of the Asymmetric Geospace**
- **Particle Precipitation**
- **Hard Radiation from Thunderstorms**

BCSS additionally houses two instrumentation groups that design, build, and operate state-of-the art space- and ground-based instrumentation, and a group dedicated to education and public outreach.

01

FROM THE CENTRE LEADER

This annual report covers the year 2020.

SCIENCE & RECOGNITION

By all accounts, this has been a very strange year. Rather abruptly, we were all working from home starting in mid-March 2020. At UiB, the restrictions were lifted by June and some of us could work from our offices. At UNIS and NTNU rules have been stricter. As a result of all the restrictions both globally and in Norway, there has been close to no travel during 2020. All international meetings have been held virtually or cancelled. Nevertheless, we have given more than 50 presentations–of which 12 have been invited talks–at international virtual meetings. Rather impressive!

We have kept up momentum with 56 publications in 2020–our second-best year since 2013. BCSS now has a total of 371 publications that have been cited 4745 times. The eight-year-old Centre has an H-index of 28 (ISI Web of Science). Our scientific results are highly acknowledged worldwide. We started the year by having our first Atmosphere-Space-Interaction-Monitor (ASIM) results on the front page of *Science* (January 10, 2020), and just one year later, another great result from ASIM (Neubert et al., 2021) made it to the front page of *Nature* (January 21, 2021). This event was picked up by more than 550 media outlets.

Just before New Year, we also received the wonderful news that the Electrojet Zeeman Imaging Explorer (EZIE) mission was selected as one of NASA's new space missions. The PI for the mission is Dr. Sam Yee from JHU-APL, with BCSS members, Prof. Jesper Gjerloev and group leader Karl Magnus Laundal, as Project Scientist and Co-Investigator, respectively. Prof. Patrick Espy is also involved as a scientific collaborator on EZIE. This $50M mission will make observations of the auroral electrojets in a completely new way, using the Zeeman effect. Dr. Laundal will be the lead of "Current Inversions" from the EZIE data.

NEW PROJECTS

Four new research projects started this year: The Trond Mohn starting grant that was given to BCSS researcher and group leader Karl Magnus Laundal–*"What Shapes Space?"*–is now up and running at full speed, along with his Research Council of Norway (RCN)-funded project *"Ionospheric Impact Response Analysis by Regional Information Integration."*

BCSS group leader Hilde Nesse Tyssøy's RCN-funded project–"*Unravelling the Drivers of Energetic Electron Precipitation: Revealing the Imprint of Space on Earth (DEEP-RISE)"* –has started. Postdocs and Phd students are now in place for the project. In the same group, Postdoc Ville Maliniemi also received significant RCN funding from the climate call for the project *"Effects of Energetic Electron Precipitation In a Changing Climate".*

These are all four-year projects that will give BCSS plenty of momentum for the next years.

INSTRUMENTS

The two-year old ASIM mission is still performing perfectly and we are receiving unprecedented data on gamma-rays and optical signals from lightning and exotic phenomena (blue jets, red sprites and elves).

The SMILE (Solar Wind Magnetosphere Ionosphere Link Explorer) project is progressing remarkably well at UIB. The launch date is now expected to be November 2024.

The new aircraft campaign *"Airborne Lightning Observatory for FEGS and TGFs"* (ALOFT), that was originally planned for 2021 has been postponed to 2023. This is due to the delay of many other campaigns planned for the two ER-2 aircraft. We now have an agreement with NASA to fly over Central America in July 2023. This is both the right season and location to observe terrestrial gamma-ray flashes and gamma-glow from an optimal distance.

The DEEP instrument, designed and built at BCSS, will be one of the instruments on the next ICI-5 bis rocket (PI: Wojciech J. Miloch, UiO). The planned launch month is February, in either 2022 or 2023.

April 2020 marks twenty years since the four Cluster spacecraft were launched. We celebrated this with a news article "The Cluster satellites keep flying", on the BCSS webpage.

In 2020, the decision was made to extend the ASIM mission throughout 2021.

LEADERSHIP

We are currently leading two international teams at the International Space Science Institute (ISSI) in Bern, Switzerland. Karl Magnus Laundal is leading *"Understanding Mesoscale Ionospheric Electrodynamics Using Regional Data Assimilation,"* which was selected in 2020. Prof. Martino Marisaldi leads the project *"Understanding the Properties of the Terrestrial Gamma-ray Flash population."* Both projects have been extended by one year.

BCSS leader Nikolai Østgaard serves as national representative in the steering committee of SCOSTEP and ISWI and Prof. Kjellmar Oksavik started as a national representative in URSI, Commission G, in 2020.

As usual, BCSS members organized scientific sessions (this year: virtual) at the EGU and AGU meetings.

ORGANIZATION

We organized a physical BCSS workshop in September. To make sure that we complied with all regulations at the time, the workshop was held at a hotel in Bergen. There were 33 in-person attendees, including a guest from the University of Tromsø. Guest lectures were given remotely from the United States, and our Science Advisory followed the workshop online.

With several new projects, BCSS has been strengthened substantially. The group "Dynamics of the Asymmetric Geospace" has now grown to a total of 24 members and the group "Particle Precipitation" to a total of 18 members. The "Hard Radiation from Thunderstorms" has 13 members.

EDUCATION AND OUTREACH

Last year, eight Master's students at BCSS received their degrees.

Physics in general has a significant gender imbalance, and it is our ambition to rectify this. It was therefore encouraging to see an interview with one of our Master's students, Amalie Øie Øverland, in the local student newspaper Studvest, where she pointed out that the gender balance at BCSS is much better than what she had experienced as a bachelor's student. At the Master's and PhD levels, BCSS now has a 50-50 split between male and female students.

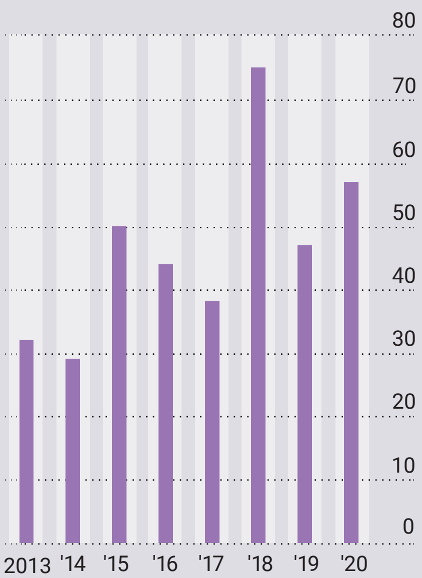
Following a *GRL* publication by Maliniemi et al. *(2020: Will Climate Change Impact Polar NOx Produced by Energetic Particle Precipitation?)*, the three members of the Particle Precipitation group, Ville Maliniemi, Hilde Nesse Tyssøy and Christine Smith-Johnsen published a popular science article in forskersonen.no.

As a final remark, I want to thank all BCSS members for making this special year one of the most productive at BCSS. Like all of you, I cross my fingers that 2021 will be more like 2019 than 2020.

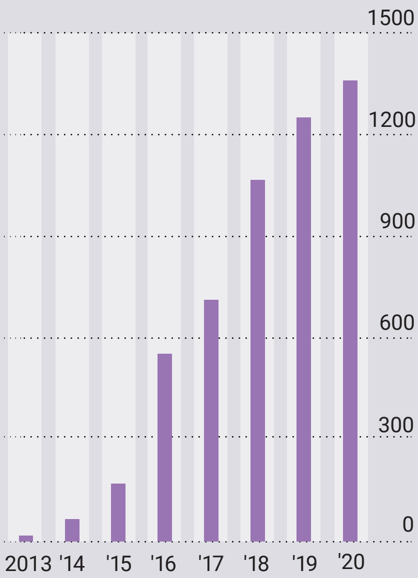
Nikolai Østgaard,
Leader of BCSS

Dissemination data

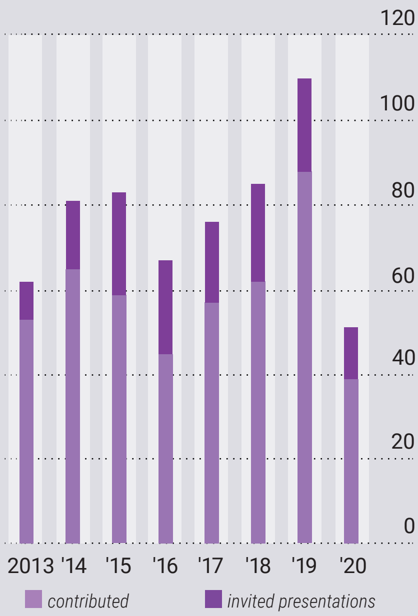
PUBLICATIONS



CITATIONS

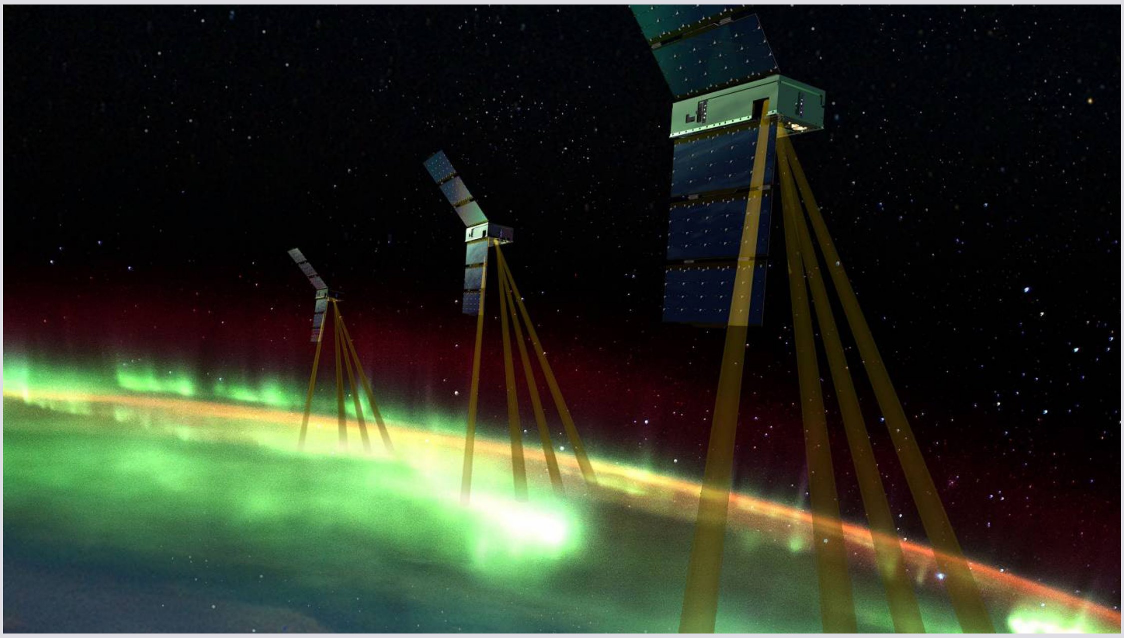


PRESENTATIONS



NASA EZIE MISSION

illustration: NASA



BCSS scientists play a central role in NASA's EZIE (Electrojet Zeeman Imaging Explorer) mission.

BCSS' drs. Jesper Gjerloev and Karl Magnus Laundal of the EZIE project

NATURE COVER

illustration: BCSS / Mount Visual / Daniel Schmelling

The January 21, 2021 *Nature* cover featured ASIM results.

02 Dynamics of the asymmetric geospace

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A running theme in the research in the Dynamics of the Asymmetric Geospace (DAG) group is the effects of different orientations in the interplanetary magnetic field (IMF) on the Earth's magnetosphere. The interplanetary magnetic field changes rapidly, but is most likely to be aligned with the Sun's equator. This means that in geocentric solar magnetic coordinates, which is used for Sun-Earth coupling processes, the IMF tends to have a strong component in the y (approximately dawn-dusk) direction. This component, so-called "IMF B_y," has long been known to affect the two hemispheres differently, and the DAG group has done groundbreaking work in the past years to understand how such hemispheric asymmetries are produced.

In a follow-up study from a 2019 paper, Katie Herlingshaw et al. analyzed the IMF B_y effects on ionospheric flow channels observed with the SuperDARN radar in Longyearbyen. Ionospheric flow channels are narrow channels where the ionospheric plasma reaches velocities of typically greater than 1 km/s. Ionospheric convection has been studied for several decades, but most studies focus on the large-scale averages and may miss the important role of these mesoscale structures. Herlingshaw et al. show (Figure 1) that flow channels are most often observed on the dayside, and that their location and direction depend on the sign of IMF B_y. The observed pattern is consistent with how we think the interplanetary magnetic field influences plasma circulation on the dayside, and we expect that it is opposite in the two hemispheres.

It has recently become clear that the sign of IMF B_y also has an effect on geospace that is symmetric between the two hemispheres. This has been termed the "explicit B_y effect". It is still debated if the explicit B_y effect results from variations in the Sun-Earth connection itself, or from variations in how the solar wind energy is stored and released in the Earth's magnetosphere-ionosphere system. Using the Milan et al. (2015) method for estimating the size of the polar cap (Figure 2), Jone Reistad et al. published a paper in *Geophysical Research Letters* in the beginning of 2020 that addresses this question. They showed that the size of the polar cap–the area near the magnetic pole enclosed by aurora–depends explicitly on IMF B_y in a fashion similar to related phenomena reported in previous studies. This finding suggests that the sign of IMF B_y, together with the orientation of the Earth's magnetic dipole axis, affects how much energy is transferred from the solar wind to the magnetosphere. This energy produces

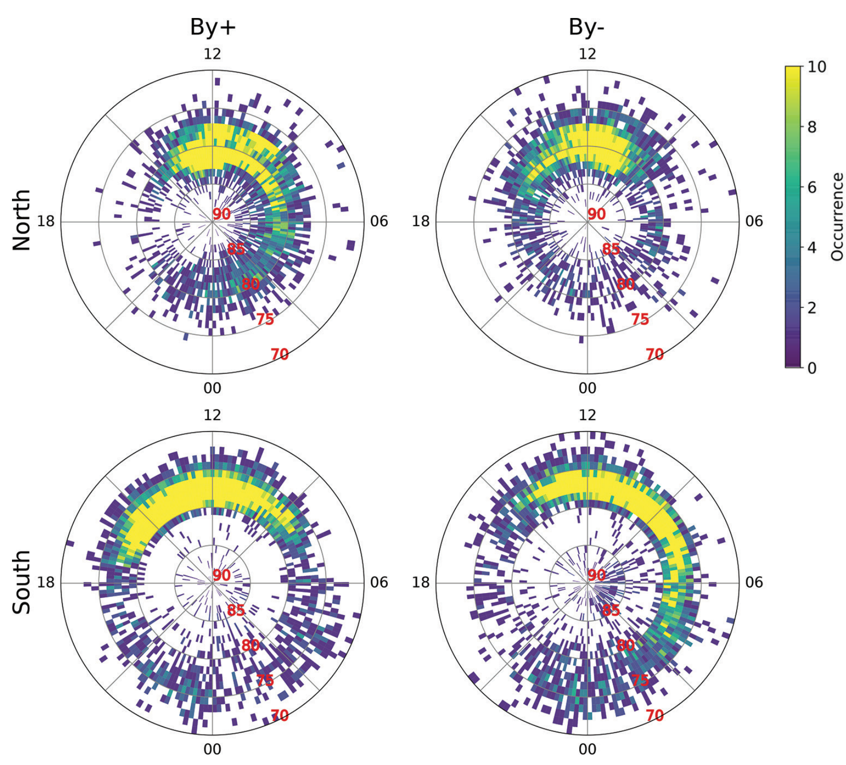

Figure 1: *(From Herlingshaw et al. (2020)* Flow channel event occurrence distributions in MLAT/MLT coordinates divided into different hemispheres and IMF B_y orientations.

Dynamics of the asymmetric geospace

auroras and potentially hazardous geomagnetic disturbances near Earth.

The energy transfer from the solar wind to the magnetosphere is not the only factor that controls geomagnetic activity. Energy transferred from the solar wind may be stored in the Earth's magnetosphere for many hours before it is released almost explosively, powering large outbreaks of aurora and ground magnetic disturbances. Laundal et al. investigated the relationship between the so-called loading (energy transfer from the solar wind) and unloading (explosive release of energy). They presented theory and experimental evidence that solar wind-driven statistical models of geomagnetic disturbances depend on time scales: Daily variations of geomagnetic disturbances appear to have a stronger link to solar wind variations than hourly variations.

The DAG group has grown significantly in the past year. Four new PhD students started: Reham Elhawary, Michael Madelaire, Sara Gasparini, and Margot Decotte. Spencer Hatch was hired as a researcher in Bergen. Steve Milan returned as a 20% professor. Despite the difficult circumstances of 2020, new group members are making very good progress on their research projects, and we look forward to exciting results in the years to come.

Many of the new group members are hired in new projects that are funded by the Trond Mohn Foundation and the Research Council of Norway. A common theme in these projects is regional data assimilation–the combination of different types of measurements in regions with high data density. This work will be an important focus area of the DAG group in the coming years, boosted by two successful proposals that were announced in 2020. The first, a proposal for an international team led by Karl Laundal, was approved by the ISSI. This will fund a team of international experts who will meet for two week-long meetings at ISSI's premises in Bern, Switzerland to discuss mesoscale ionospheric electrodynamics and regional data assimilation. The second, the EZIE satellite mission selected by NASA in late 2020, also heavily involves DAG researchers: Professor-II Jesper Gjerloev as a project scientist, and Karl Laundal as Co-I. After launch in 2024, three EZIE satellites will scan the electrojet in a ~1000 km wide region along the satellite tracks. They will do this by observing the Zeeman split in Oxygen emissions from the mesosphere, which will be used to derive magnetic field disturbances. Karl Laundal is responsible for the calculation of electrojet maps from these magnetic field measurements.

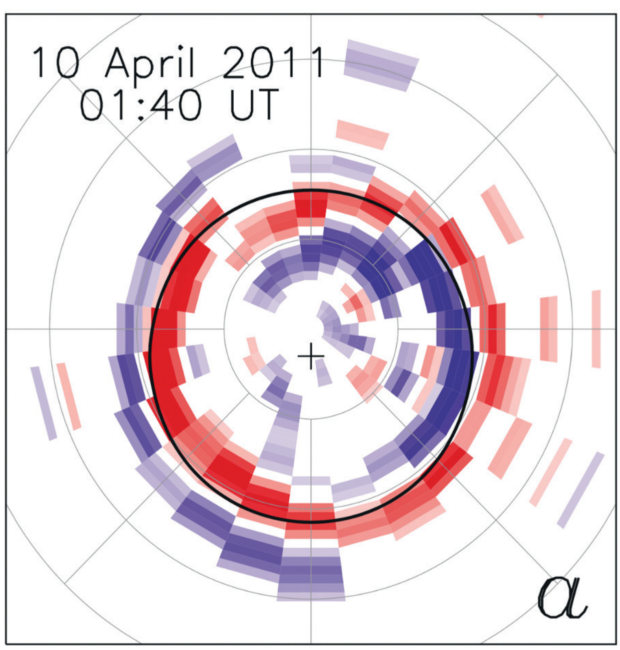

Figure 2: *(From Milan et al. (2015)* Polar maps of Birkeland currents, derived from Iridium magnetometer measurements were used to estimate the size of the polar cap (black ring). The same method was used by *Jone Reistad et al. (2020)* to show that the size of this area depends on the sign of the IMF B_y and on the tilt angle of the Earth's dipole axis. This effect is not taken into account in existing theories for solar wind-magnetosphere coupling.

03 Particle precipitation

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Particle precipitation

The impact of energetic particles on the atmosphere links space physics, atmospheric chemistry and dynamics, all the way to the winter weather on ground. Storms in space result in acceleration of electrons and protons in the solar wind and the magnetosphere. Guided by the Earth's magnetic field, a part of this energy is deposited in the atmosphere. The subsequent ionization of the neutral atmosphere initiates chemical reactions leading to the production of odd nitrogen (NOx: N, NO, NO2) and odd hydrogen (HOx: H, OH, HO2) species. In the polar winter darkness, odd nitrogen has a long lifetime, allowing the seasonal downwelling to bring excess NOx into the upper stratosphere. Here it can reduce the ozone concentration in catalytic reactions. Ozone is critically important in the energy budget, so changes in ozone can impact temperature and winds which can then link to our weather systems. The PP group brings together space and atmospheric scientists with the expertise to unravel the complex relationship between energetic particle precipitation (EPP) and its atmospheric effects applying both observations and models.

Anthropogenic climate change is increasing tropospheric temperatures globally via enhanced greenhouse gas emissions. This is particularly dramatic in the high latitudes, where temperatures are expected to rise by several degrees by the end of this century. Furthermore, these changes are also prominent in the middle atmosphere, where notable cooling trend is already observed and predicted to continue. The global meridional circulation in the stratosphere and the mesosphere is expected to change and therefore modify polar mesospheric descent rates. Thus, one of the outstanding questions is whether the changing climate will also influence the strength and pathways of the EPP signal. In Maliniemi et al. (2020) this hypothesis was tested. We investigated the Southern Hemispheric polar NOx distribution during the 21st century under a variety of future scenarios using simulations of the Whole Atmosphere Community Climate Model (WACCM). Stronger polar mesospheric descent was found in all future scenarios that increase the atmospheric radiative forcing. Polar NOx in the upper stratosphere was significantly enhanced in the two future scenarios with the largest increase in radiative forcing. In conclusion, this dynamical change implies that the EPP impact on the atmosphere may become more prominent in the future.

The role of the background atmosphere is further explored in the new RCN research project "Effects of energetic electron Precipitation In a Changing climate (EPIC)" with Ville Maliniemi as the PI. EPIC started early in September with hiring of Jone Edvartsen as a new PhD student, a zoom kick-off meeting, followed by a visit from guest researcher Pavle Arsenovic. During the visit the atmospheric climate model SOCOL was set up to run on Norwegian super computers. In parallel, the WACCM free running mode with D-region chemistry is implemented in different background atmospheres in collaboration with Bjerknes Centre for Climate Research and NORCE. As a result, several interesting findings and papers are in the pipeline.

Another new RCN project is the "Unravelling the Drivers of Energetic Electron Precipitation–Revealing the Imprint of Space

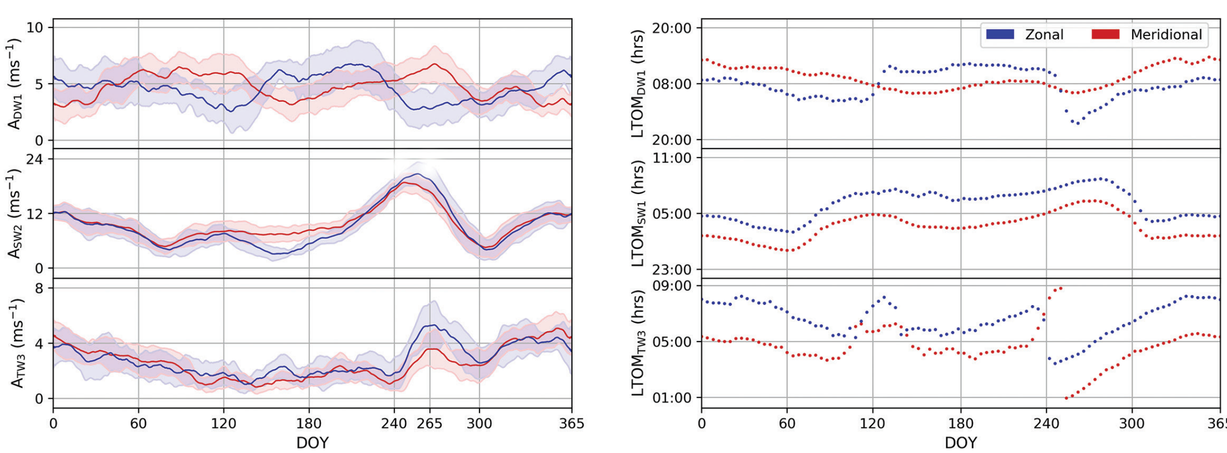

Figure 3: Illustration of the amplitude *(left)* and phase *(right)* variability of the 24-hr diurnal (top), 12-hr semidiurnal *(middle)* and 8-hr terdirunal *(bottom)* tidal wind variations in the atmosphere. While mean winds are near zero around the equinox, this work shows that tidal oscillations are near their maximum during autumn and their minimum near spring.

on Earth (DEEP - RISE)" with Hilde Nesse Tyssøy as the PI. This is a direct successor to the Young Centre for Advanced Study (CAS) working group with a shared goal to achieve a holistic view on the causes of energetic electron precipitation and its dependence on solar wind structures and magnetospheric processes, to better estimate the occurrence, duration and strength of the energetic electron precipitation and the subsequent impact on the atmosphere. Josephine Salice, a new PhD candidate, showed in her Master's thesis that the sequence of the solar wind structures, Coronal Mass Ejections (CME) and Corotating Interaction Regions (CIR) events, were important to determine the flux in the high energy tail of the electron precipitation (>300 keV) (Salice, 2020).

High energy electrons are often associated with pulsating aurora (PsA). Tesema et al. (2020a) investigated the combined particle measurement from multiple spacecrafts associated with the optical signature of the pulsating aurora. The energy spectrum ranging from non-relativistic to relativistic (30 eV to 1,000 keV) electrons were obtained. The median spectrum was further applied in the Sodankylä Ion-neutral Chemistry (SIC) model to assess the chemical effect of PsA electrons. The observed extreme and median spectra of PsA was found to produce a significant depletion in the mesospheric odd oxygen concentration up to 80% of mesospheric ozone for two days. A follow-up morphological study on pulsating aurora suggested that the lack of atmospheric impact during some pulsating aurora events may come from a specific morphological class of pulsating aurora called amorphous pulsating aurora (Tesema et al., 2020b).

To determine the impact of EPP on the temperature of the mesopause region, spectroscopy of the OH airglow is a widely used observational technique. Franzen et al. (2020) considered the consequences of observing an OH spectrum through a layer in the atmosphere that was itself perturbed by realistic atmospheric waves. They found that typical temperature perturbations caused by gravity waves could generate an apparent non-thermalized excess population in the upper rotational states of the OH radical that could be interpreted as a non-Boltzmann distribution if the OH rotational line strengths were fitted to a single temperature. Previous studies have suggested that the OH radical itself is actually observed in the mesopause in a non-thermal state as a consequence of its highly

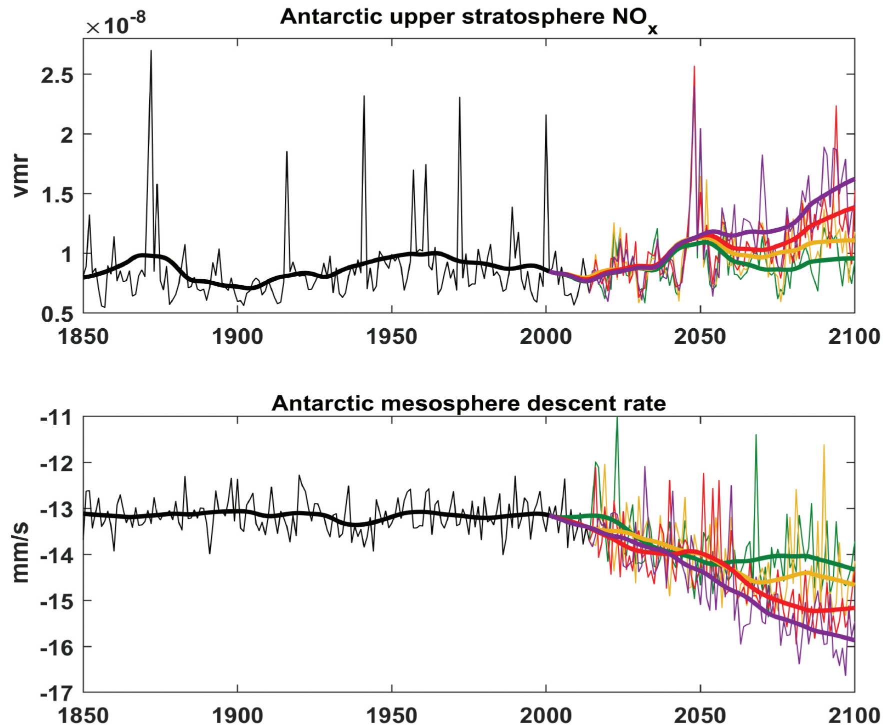

Figure 4: Winter NOx in the Antarctic upper stratosphere and descent rate in the mesosphere.
Black = 1850-2014 historical run,
Green = 2015-2100 SSP1,
Yellow = 2015-2100 SSP2,
Red = 2015-2100 SSP3, and
Purple = 2015-2100 SSP5.
Thin lines represent winter average and thick lines repre- sent 31-year smoothed trend.

exothermic formation reaction. Franzen et al. (2020) demonstrated that up to 40% of the excess population previously attributed to incomplete thermalization can in fact be due to the vertical temperature gradients created by waves. They conclude that careful consideration of the true temperature profile in the airglow layer is required in order to infer OH rotational level population distributions, and hence to derive realistic temperatures from ground-based airglow observations.

Tidal oscillations of the wind represent the largest source of variability in the mesosphere–lower thermosphere (MLT). van Caspel et al. (2020) demonstrated that hourly meteor wind measurements from a longitudinal array of 10 high-latitude SuperDARN high-frequency (HF) radars can be used to isolate the migrating diurnal, semidiurnal, and terdiurnal tides in the MLT. The study utilized the radar measurements in conjunction with the Navy Global Environmental Model–High Altitude (NAVGEM—HA) model to show the effectiveness of the radar measurements in separating the migrating from the non-migrating components. Distinguishing between the components, which is impossible to do from a single-station and quantifying their seasonal behavior is critical to understanding how these solar-driven, global oscillations can mask, or even mimic, perturbations that particle precipitation may cause, a key goal of the BCSS.

The year 2020 was projected to be busy for the PP group in terms of conferences and working group meetings, where organizing the HEPPA-SOLARIS workshop in Bergen was intended to be the highlight. The lockdown, however, forced us to postpone it indefinitely until travel restrictions are revoked. Smaller international working group meetings, such as the CAS and SOLARIS-HEPPA working groups, have however thrived. During 2020, the PP group published 19 papers, six Master's students successfully completed their thesis, and the results of Maliniemi et al. (2020) were promoted in a popular science paper at forskersonen.no.

04 Hard radiation from thunderstorms

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Ragnar Landet, UiB
Master's Student

It has been known for 20 years that thunderclouds are the most energetic natural particle accelerators on Earth, capable of accelerating electrons up to relativistic speed and of producing photons of energies up to several tens of mega-electronvolts, which is more than ten times the maximum photon energy that is associated with natural radioactivity. In addition to electrons and photons, positrons and neutrons are also observed in association with thunderstorms. All this energetic radiation is emitted at very different timescales, from sub-millisecond terrestrial gamma-ray flashes (TGFs) to minute-long gamma-ray glows. The emerging research field, aptly named "high-energy atmospheric physics," is dedicated to the understanding of this variety of energetic phenomena and its impact on the surrounding environment and is the core focus of BCSS Group "Hard Radiation from Thunderstorms" (HRT).

The core activity of HRT group this year has been the scientific exploitation of the ASIM data. This culminated with the paper *"Observation of the onset of a blue jet into the stratosphere,"* by Neubert et al., published in *Nature* and awarded the front page of the January 20, 2021, issue of the prestigious journal. Blue jets are discharges that originate from thundercloud tops and propagate upwards into the stratosphere, where common lightning activity does not take place. The paper reports the observation of five such events by the optical instrument (MMIA) onboard ASIM, their high-altitude (stratospheric) origin being confirmed by the dominance of 'blue' and 'ultraviolet' optical bands over the 'red' band, which is the band where most of the signal from 'typical' lightning is concentrated.

In addition to ASIM-related activity, here we highlight three papers written by the HRT PhD students and not related to ASIM data. *"The 3rd AGILE Terrestrial Gamma Ray Flash Catalog. Part I: Association to Lightning Sferics"* by Lindanger et al. (2020) and *"The 3rd AGILE Terrestrial Gamma-ray Flashes Catalog. Part II: Optimized Selection Criteria and Characteristics of the New Sample"* by Maiorana et al. (2020) are two companion papers that explore in detail the wealth of TGFs detected by the AGILE satellite over a three-year period. This period followed the update of the onboard configuration that resulted in a ten-fold enhancement in its TGFs detection capabilities. The paper by Lindanger et al. explores the association of AGILE TGFs and lightning sferics, resulting in almost 600 events with reliable source

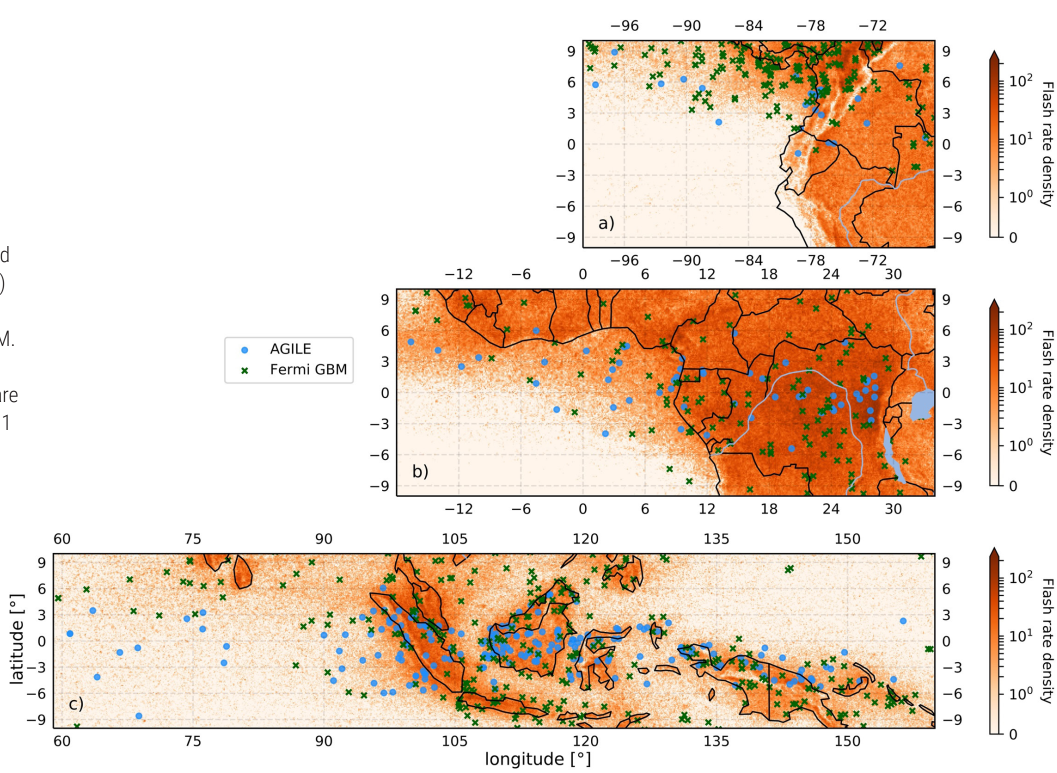

Figure 5: *(From Lindanger et al., 2020)* The position WWLLN (World Wide Lightning Location Network) matches associated to TGFs detected by AGILE and Fermi-GBM. The color scale shows flash rate density with unit flashes per square kilometer per year from the LIS 0.1 Degree VHRFC dataset.

Hard radiation from thunderstorms

location estimate and confirming results previously reported only by the Fermi satellite. This paper also identified the first Terrestrial Electron Beam (TEB) detected by AGILE. The paper by Maiorana et al. reports the design of improved selection criteria to identify TGFs in the AGILE data, resulting in almost 3000 TGFs, which are then characterized in terms of geographical properties and seasonal characteristics resulting in an unprecedented detailed view of the TGF population across the equatorial region. The event catalogs associated with both papers are accessible online through a dedicated interface and provide a valuable tool to the scientific community.

The paper *"Constraints on Recoil Leader Properties Estimated from X-ray Emissions in Aircraft-Triggered Discharges"* by Skeie et al. (2020) investigates microsecond-long bursts of X-rays observed inside an Airbus aircraft during dedicated flight campaign into thunderstorms. These bursts are associated with recoil current pulses in lightning discharges triggered by the aircraft itself. Modeling of the X-ray pulses allowed the constraint of the length of the leader (the conductive channel of a lightning discharge), and the gap between the leader tip and the aircraft, at the time of X-ray production. This provides an original diagnostic tool for a phenomenon that is pervasive (aircrafts are routinely hit by lightning, most of them triggered by the aircraft passage itself) but historically difficult to characterize due to its sporadic and disruptive behavior.

As TGFs in the pre-ASIM era have been mostly detected from space by instruments dedicated to gamma-ray astrophysics, and gamma-ray bursts (GRB) in particular, here we highlight that ASIM has also proven to be a successful GRB detector: ASIM observed several very short and bright GRBs; these were promptly reported to the astrophysics community by means of the so-called 'GRB Coordinates Network (GCN) circulars. Although the detected events are only a small fraction of the large number of GRBs routinely observed by dedicated missions (roughly one per day), the observed events are highly significant because they match the scenario of neutron star mergers possibly associated with the detection of gravitational waves, or other exotic phenomena such as giant flares from highly magnetized neutron stars (magnetars). The strength of the ASIM observations for these events is the excellent time resolution and the tolerance to very high fluxes. These qualities make ASIM observations desirable for events that involve the most intense gamma-ray transients in the universe, capable of significantly hampering the detection capabilities of other instruments. This is now triggering a lot of activity and collaboration efforts in our group, allowing us to branch and reach out in unexpected directions and bridge to neighboring yet previously separated scientific communities.

As in the previous years, team members were actively involved as conveners of topical sessions at the annual plenary meetings of the European Geosciences Union (EGU) and American Geophysical Union (AGU), both held online this year. Team members contributed to these and other relevant international conferences with more than 20 presentations, including one invited talk at the JpGU - AGU joint meeting, plus two invited seminars at international institutions. ●

05 Space instrumentation

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Chief Engineer

Thomas Poulianitis, UiB
Chief Engineer

Bilal Hasan Qureshi, UiB
Chief Engineer

Viljar Dahle, UiB
Master's Student

Bendik Husa, UiB
Master's Student

Space instrumentation

ASIM

The Atmosphere-Space Interactions Monitor (ASIM) continues to deliver unprecedented data of terrestrial gamma-ray flashes (TGFs), galactic gamma-ray bursts (GRBs), lightning strokes and other exotic phenomena like blue jets and elves. Following the success of having simultaneous TGF and elve events on the front page of *Science* at the beginning of the year (Neubert & Østgaard et al. 2020), ASIM results were featured on the front page of *Nature* in January 2021 (Neubert et al., 2021)–this time with a blue jet and an elve during the same lightning flash.

ASIM is comprised of two instruments: 1) "Modular X- and Gamma-ray Sensor" (MXGS), which images and obtains spectral measurements of TGFs and now also GRBs, and 2) Modular Multi-Spectral Imaging Assembly (MMIA), designed and built by Danish Technical University and TERMA in Denmark. MXGS is designed to detect gamma-rays in two energy bands, 50-400 keV and 0.3-30MeV. The two detector layers and read-out electronics of the MXGS instrument were designed and built by the BCSS instrumentation group. The MMIA instrument has three photometers and two cameras to image and obtain spectral measurements of lightning and Transient Luminous Events.

ASIM was planned for a two-year mission ending summer 2020, but due to its success it has been officially extended throughout 2021. BCSS supports the ASIM Science Data Center (ADSC) with a dedicated programmer/researcher funded through ESA-PRODEX program.

SMILE

The Solar Wind Magnetosphere Ionosphere Link Explorer (SMILE) mission is a joint mission of the European Space Agency (ESA) and the Chinese Academy of Science (CAS). Launch is planned towards the end of 2024.

One of the instruments on board SMILE is the Soft X-ray Imager (SXI), which will provide unprecedented images of the entry of plasma from the Sun into the Earth's magnetosphere. The SXI project is a collaboration between several European universities, research institutes, and industrial partners. BCSS will deliver a Radiation Shutter to protect the SXI instrument against fatal exposure during spacecraft maneuvers and crossings of the Earth's radiation belt. The Radiation Shutter is comprised of the Radiation Shutter Mechanism (RSM) and Electronics (RSE).

In 2020 the launch date was pushed back one year, because many suppliers and involved parties were closed for an extended time. Our focus was therefore on improvements of the second version of the breadboard models for both RSM and RSE. A series of vibration tests were executed at Prototech in Bergen. Small design improvements were implemented between each vibration test. BCSS is now confident that the RSM mechanical design is robust and suitable for SMILE. The test campaign will continue with shock and thermal testing in the beginning of 2021.

Photo: Maja Rostad

Figure 6: UiB engineers Nuno Roque (left) and Georgi Genov setting up the second bread board of the Radiation Shutter Bread Board (RSM BB2) on the vibration shaker at Prototech.

Photo: Maja Rostad

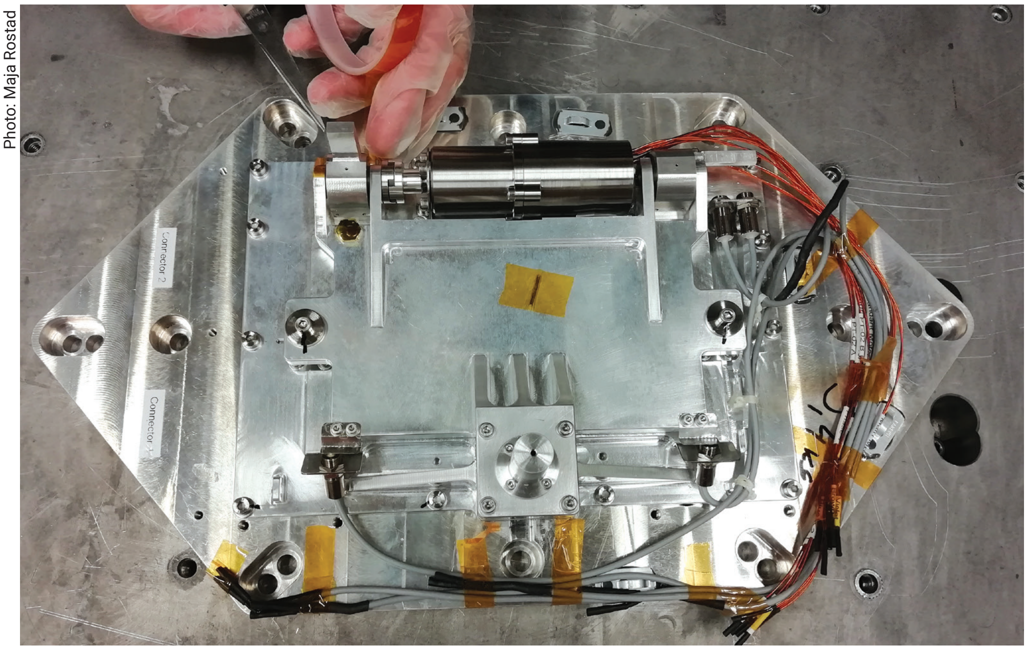

Figure 7: The second bread board of the Radiation Shutter Bread Board (RSM BB2) mounted on a test jig (diamond shaped outline), in preparation for vibration testing at Prototech.

Most electronics components and components with long lead time for the Engineering Qualification Models (EQMs) were delivered in 2020. The rest is expected to be delivered within the first couple of months of 2021. At the end of 2020 BCSS also manufactured, assembled and delivered an RSM mass dummy for the SXI instrument level structural and thermal verification model.

A lot of work has also gone into design documentation and various analyses (part stress, reliability, thermal, and worst case analysis, etc.) needed for input to the Critical Design Review (CDR). The CDR is currently scheduled for the third quarter of 2021.

The ESA PRODEX contract is now extended and approved through 2023. It now covers all hardware activities from breadboard to flight models. The total BCSS involvement in SMILE is approximately 29 MNOK, including in-kind assistance from UiB. The PRODEX funding is 1345 kEUR.

DEEP

Accurately quantifying the effect of energetic particle precipitation requires a good estimate of the energy deposited in the atmosphere and how the energy is distributed globally. The design and/or orbit of current particle detectors in space are inadequate for determining the number of particles precipitating into the atmosphere. The electrons in particular often have a strong anisotropic pitch angle distribution. Adequately measuring the shape of this distribution is essential to determine the particle loss to the atmosphere. DEEP is composed of three electron- and three proton-pixelated detectors in separate housings, covering a field of view of 180° and energies from 30 keV to 1500 keV (electrons) and 30 keV to 10 MeV (protons). This makes it possible to determine the electron fluxes absorbed by the atmosphere, as well as the fluxes backscattered from the atmosphere.

The DEEP prototype was launched back in 2019, and in 2020 the focus has been on developing the next model of DEEP for a potential launch in 2022/2023.

ALOFT

A new ALOFT campaign is now planned for July 2023. This time the ER-2 aircraft will fly at 20 km altitude over Central America, Caribbean and northwest South America. These regions are hot spots for TGF production and the most intense season is July through September. ALOFT will make high-resolution measurements of both the gamma rays, optical signals, and electric field. The main objective is to measure TGFs from an optimal venue point, but will also spend 1/3 of the flight time to search for and follow the long-lasting gamma-ray glows from thunderclouds. ALOFT is a collaboration between BCSS, University of Alabama, Hunstville and NASA Marshall Space Flight Center. BCSS will fly one of the units from ASIM High Energy Detector, which consists of 3 BGO/PMT. In addition, we will build a few smaller detectors to prepare for extremely high gamma-ray fluxes. ●

06 Ground-based instrumentation

Fred Sigernes, UNIS
Professor, Team Leader

Dag Lorentzen, UNIS
Professor & Co-leader

Robert Hibbins, NTNU
Professor

Lisa Baddeley, UNIS
Assoc. Professor

Mikko Syrjäsuo, UNIS
Chief Engineer

Adrienne Oudijk, UNIS
Master's Student

The ground-based instrumentation group runs and maintains already-existing research infrastructure that the BCSS is granted access to. This includes the Kjell Henriksen Observatory (KHO) and NTNU's meteor radar, as well as optical instrumentation at Dragvoll campus in Trondheim and the LINET receiver in Bergen. The Scintillation and Total Electron Content (TEC) network of BCSS is also included in the infrastructure. This section reports on the main activity in 2020.

KJELL HENRIKSEN OBSERVATORY

KHO has now operated successfully for 12 years and is the largest facility of its kind for optical instruments studying the aurora. During the auroral winter season from November to the end of February, 28 optical instruments operate 24 hours a day. The 17 non-optical instruments run year-round, 24 hours a day. 24 different institutions from 14 nations are present at KHO.

The activity at the Kjell Henriksen Observatory (KHO) has been low after the outbreak of the COVID-19 in March. No rocket campaigns have been carried out and no visits from our instrumental partners have occurred.

The observatory serves as the main laboratory for hands-on training and teaching of students in the Space physics group at UNIS. Only three courses have used it as part of field work, producing a grand total of 35 ECTS, which is less than 50% of a normal year.

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. They all managed to finish their courses and degrees successfully. Four Master's students graduated from our group in 2020 and 20 papers were published.

After 40 years of operation, the Silver Bullet 1m Ebert-Fastie spectrometer 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 1980s. 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.

Figure 8: Fieldwork for AGF-301 students. The students studied real-time solar wind data from the Deep Space Climate Observatory (DSOVR) satellite and the predicted lead time of the aurora. Date is February 19, 2020.

Photo: Mikko Syrjäsuo

Ground-based instrumentation

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

Our app, named Aurora Forecast 3D, is rated 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 tourist industry and in the amateur radio community. The Facebook page for KHO has 1516 followers.

NTNU GROUND-BASED INSTRUMENTS

NTNU's ground-based long-term monitoring programme consists of recording continuous middle atmosphere winds, temperatures and gravity-wave momentum flux from the group's Skiymet meteor radar system, and hydroxyl temperatures and radiances recorded with a compact near-infrared spectrometer together with collaborative projects with a large number of international groups.

Complementing this observational effort, the final paper from Dr. Christoph Franzen's PhD thesis, "Modelled effects of temperature gradients and waves on the hydroxyl rotational distribution in ground-based airglow measurements," was published in 2020. In this work, carried out for the BCSS, he was able to clarify the role that waves play in producing non-thermal OH distributions, and to validate a method of obtaining reliable temperature measurements in the face of such non-linear effects.

BCSS PhD student Wim van Caspel used the longitudinal chain of northern hemisphere SuperDARN radars to quantify the variability of atmospheric tides in his 2020 publication "Migrating tide climatologies measured by a high-latitude array of SuperDARN HF radars." These radars, which extend the NTNU meteor radar data back to 2000, give a global picture of these tidal motions that represent the largest source of wind variability in the middle atmosphere. Understanding how these large tidal amplitudes and phases change in time is critical to understanding how perturbations caused by particle precipitation, a key goal of the BCSS, can be quantified in the face of these much larger background variations.

Results from NTNU's instrumentation have been presented at international meetings run by the AGU, EGU, AOGS and JpGU during 2020 and have formed a core component of three Master's student theses submitted during the past year.

GNSS RECEIVER NETWORK

BCSS operates four scintillation and total electron content receivers that record signals from navigation satellites over Svalbard and the Barents Sea. The 60-second data have been published in the repository DataverseNO. This collection currently contains 57 sub data sets for the years 2013-2019. In 2020 there were several data gaps due to hardware issues. Data recording resumed in the autumn of 2020 after the replacement of hard drives and operating software. In 2020 measurements from this low-cost research infrastructure contributed to scientific publications on plasma irregularities associated with field aligned currents and cusp flow channels.

LINET

We have maintained the Bergen LINET station, which is a VLF/LF radio receiver that is part of the lightning detection network LINET. The LINET network was developed by the University of Munich and is now managed by Nowcast GmbH. The combined use of ASIM and LINET data is included in a PhD project at BCSS, part of the SAINT project, that started December 2017. SAINT is a Marie Curie network with 10 partners funding 15 PhD students in Europe.

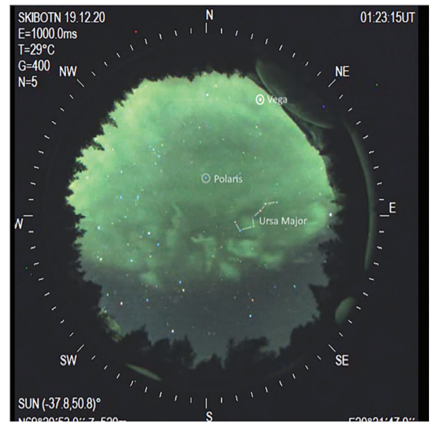

Figure 9: BACC #5 All-sky color camera movie snapshot from the Skibotn Observatory (SKN) on the 19th of December 2020. Typical post-midnight structured aurora related to night side sub storm.

07 Education and public outreach

Kjellmar Oksavik, UiB
Team Leader, Professor

Arve Aksnes, UiB
Advisor, PhD

Kjartan Olafsson, UiB
Advisor, Assoc. Professor

Kavitha Østgaard, UiB
Senior Consultant

Education and public outreach

During 2020, BCSS researchers have contributed to 56 publications in scientific journals and 52 presentations (including 12 invited talks) at international conferences.

ASIM RESULT HIGHLIGHTS

Since it was launched and mounted outside the International Space Station in 2018, the ASIM instrument has led to many groundbreaking results about gamma-ray flashes and lightning. This has been met with international recognition, and examplified by an almost impossible achievement: a front-pages each in *Science* and *Nature* during a 12-month period.

The most recent ASIM-based study of blue jets, which was featured on the cover page of *Nature* in January 2021, resulted in more than 600 media news items in less than three weeks. News outlets included *Science News*, *ESA*, *NASA*, *BBC*, *The Independent*, *NRK* and *El Pais*.

CLIMATE CHANGE, AURORA, OZONE

What is the connection between climate change, the aurora and the ozone layer? In May, Ville Maliniemi, Hilde Nesse Tyssøy and Christine Smith-Johnsen of the Particle Precipitation group published a popular science article on forskersonen.no (in Norwegian) about their recent *GRL* publication entitled "Will climate change impact polar NOx produced by energetic particle precipitation?".

Illustration: Mount Visual / Daniel Schmelling

Illustration: BCSS / Mount Visual / Daniel Schmelling

Figure 10: Cover pages of, respectively, *Science* (January 2020) and *Nature* (January 2021).

Kan mekanismane bak det vakre nordlyset påverka veret? (Foto: Heiko Junge / NTB Scanpix)

Kan framtidas nordlys vera eit varsel om ein mild vinter?

POPULÆRVITENSKAP: Nordlyset har gjeve opphav til mange myter. Tidlegare vart det mellom anna kalla verljoset og brukt som eit vervarsel. Er dette berre ei myte, eller kan dei usynlege mekanismane bak det vakre lyset verkeleg påverka veret?

Ville Maliniemi, Hilde Nesse Tyssøy og Christine Smith-Jonsen
BIRKELANDSENTERET FOR ROMFORSKNING

Figure 11: Popular science article by Ville Maliniemi et al. featured in forskersonen.no.

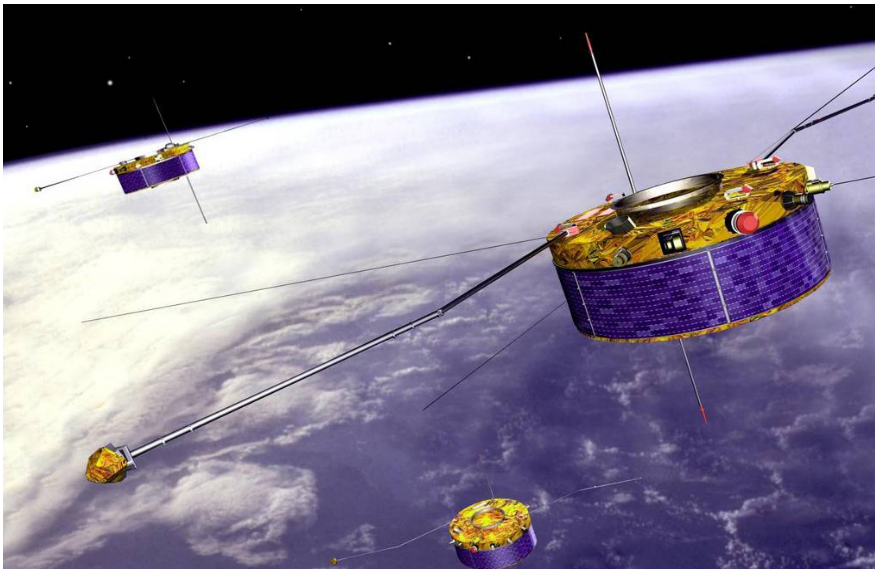

Figure 12: Artist's rendition of Cluster spacecraft

MASTER'S STUDENT INTERVIEWED

On October 22, Master's student Amalie Øie Hovland, a member of the BCSS group "Dynamics of the Asymmetric Geospace," was interviewed by the UiB student paper *Studvest.* In the article, Amalie explains her work towards her Master's thesis. She also points out that she enjoys the academic environment as a student at the Birkeland Centre for Space Science, where there is a much better gender balance compared to what she has experienced earlier as a bachelor student and in physics in general, which has traditionally been dominated by men.

CLUSTER SATELLITES KEEP FLYING

April 2020 marked the 20th anniversary of the launch of the four Cluster satellites, whose mission was to perform a 3D investigation of the Earth's magnetosphere. This ESA mission involved 18 different countries, with Norway being one of the four largest contributors. BCSS (then known as the Space Physics Group at UiB) has played an important part throughout the entire Cluster mission, building part of the RAPID instrument that is onboard as well as performing data analysis. To highlight the 20-year anniversary of the mission, we have written an article on the Birkeland homepage entitled "The Cluster satellites keep flying." Here, we present numerous examples from recent years–including 2020–of publications by BCSS researchers using Cluster data.

INTERVIEW ON NRK TV PROGRAM

Prof. Fred Sigernes (UNIS) was interviewed on a four-part NRK TV program called "Snowhow: the Nordic Winter" in January 2020. The series touches on how winter has formed the world we live in and how we humans have adapted to it.

NIKOLAI ØSTGAARD ON TV2

The first NASA manned launch since 2011 was scheduled for the 27th of May 2020, as a SpaceX rocket with Crew Dragon capsule was to carry two American astronauts to ISS. The Norwegian channel TV2 televised a live report on the launch preparations, and among the expert panel on hand was Centre Leader Nikolai Østgaard. He discussed the April 2018 launch of the ASIM instrument–parts of which were produced by BCSS–on another SpaceX rocket. The interview focused on the ASIM launch to the Columbus module of the ISS and subsequent commissioning of the instrument.

Figure 13: BCSS Master's student Amalie Øie Hovland

Figure 14: Prof. Fred Sigernes of UNIS profiled on the TV series "Snow How"

08 Statistics

PROJECT FUNDING

Birkeland Centre for Space Science: CoE Funding 160 MNOK; Total Funding over ten years 440 MNOK

European Space Agency | Swarm+Coupling High-Low Atmosphere Interactions | Project: 4000126731

2019-2021	Info from Swarm and other satellites will be used to fill knowledge gaps related to "energetic ion outflow"	P.I. Spencer Hatch **150 KEUR**

European Space Agency | ASDC | Project: 4000123438

2018-2021	ASIM Science Data Centre (project extended, funding increased)	P.I. Nikolai Østgaard **335 KEUR**

European Space Agency | SMILE Phase 1 | Project: 4000123238

2018-2023	Radiation Shutter for SXI on SMILE (project extended, funding increased)	P.I. Nikolai Østgaard **1,345 MEUR**

European Space Agency | SWARM DISC ITT 1.3 | Project: 4000109587/13/I-NB SWARM ESL

2017-2021	Production and visualization of a climatological model of high latitude ionospheric and field aligned current systems (project extended, funding incresed)	P.I. Karl Magnus Laundal **168 KEUR**

European Space Agency | Atmosphere-Space Interaction Monitor | Project: 40000101107/10/NL/BJ |TERMA DTU: TER_SPACE:CON_DTU_SPACE-002_rev2

2010-2023	This project started September 2010 and is an ESA contract to design and build the front-end electronics and detector arrays for Modular X- and Gamma-ray flashes (MXGS). ASIM is a playload for the ISS and was launched in 2018	P.I. Nikolai Østgaard **3,75 MEUR**

Research Council of Norway | Which types of particle precipitation matter in the middle atmosphere? | Project: 287427

2019-2022	Which types of particle precipitation are important for the chemistry of the atmosphere?	P.I. Noora Partamies **7 MNOK**

Research Council of Norway | FREPPIMA | Project: 263008/F50

2017-2020	Full Range Energetic Particle Precipitation Impacting the Middle Atmosphere	P.I. Hilde Nesse Tyssøy **3,52 MNOK**

Research Council of Norway | Program for Space Research | Project: 195385

2010-2021	Infrastructure for space physics-related research on Svalbard	P.I. Dag Lorentzen **9,1 MNOK**

Research Council of Norway | Magnetic pulsations and transients: the Sun-Earth connection and impact on the high latitude ionosphere | Project: 309135

2020-2024	INTPART Coordination and Support Activity Support for Network-related Activities	P.I. Lisa Baddeley **2,118 MNOK**

Research Council of Norway | Unravelling the Drivers of EEP – Revealing the Imprint of Space on Earth (DEEP - RISE) | Project: 302040

2020-2023	The main objective is to quantify the radiation belt loss of energetic electrons into the atmosphere.	P.I. Hilde Nesse Tyssøy **4,936 MNOK**

Research Council of Norway | Ionospheric Impact Response Analysis by Regional Information Integration | Project: 300844

2020-2025	The primary project objective is to determine how ionospheric conditions affect transient geospace phenomena like substorms and rapid changes in dynamic solar wind pressure.	P.I. Karl Magnus Laundal **11,055 MNOK**

Research Council of Norway | Effects of Energetic Electron Precipitation In a Changing climate | Project: 300724

2020-2023	The primary project objective is to determine how ionospheric conditions affect transient geospace phenomena like substorms and rapid changes in dynamic solar wind pressure.	P.I. Ville Maliniemi **5,826 MNOK**

Research Council of Norway | Charged Cloud Generator (VIS project owner) | Project: 310774

2020-2020	The objectives of this project are: to verify Charge Cloud Generator as a system that can be used between 1500-2000kV, to secure IP and design CCG a modular and scalable solution, and to get industry partnership to help realize CCG in the market.	P.I. Pavlo Kochkin **275 KNOK**

Norwegian Space Agency | DEEP | Project: VIT.02.19.7

2019-2020	DEEP – Electron and Proton Detector	P.I. Hilde N. Tyssøy **400 KNOK**

Trond Mohn Foundation | What Shapes Space? | Project: TMS2020STG02

2020-2024	The project investigates the time scales of large-scale changes in geospace, and how these time scales differ between hemispheres.	P.I. Karl Magnus Laundal **9,247 MNOK**

EU-MCSA SAINT | Grant: 722337 — SAINT (Science and Innovation with Thunderstorms)

2017-2021	**SAINT** – project with a multidisciplinary and inter-sectorial training platform for 15 ESRs. The platform brings together satellite and ground observations with modelling and lab experiments.	P.I. Nikolai Østgaard **286 KEUR**

PERSONNEL

Summary

	TOTAL	UiB	NTNU	UNIS	MEN	WOMEN
Professors	9	5	2	2	9	-
Associate Professors	4	2	-	2	2	2
Professors Emeriti	2	2	-	-	2	-
Researchers	11	11	-	-	9	2
Postdocs	7	5	1	1	6	1
PhD Candidates	16	12	1	3	9	7
Technicians	6	5	-	1	5	1
Administration	3	3	-	-	1	2
Master's Students	16	9	4	3	10	6
Sum	74	54	8	13	53	21

Science Advisory Board (SAB)

Hermann Opgenoorth, *Prof. Emeritus, Umeå University*	SWE
Kristi Kauristie, *PhD, Finnish Meteorological Institute*	FIN
Steve Cummer, *Professor, Duke University*	USA

BCSS Team

Centre Leader	Nikolai Østgaard	UiB
Adm. Coordinator	Katarzyna Kosela-Dordevic	UiB
Centre Board	Anne Marit Blokhus, *Vice-Dean, Faculty of Math. & Natural Sciences*	UiB
	Elisabeth Müller Lysebo *Dep. Dir. Genl., Fac. of Math. Nat. Sci.*	UiB
	Øyvind Frette, *Head, Dept. of Physics and Technology (IFT)*	UiB
	Erik Wahlström, *Head, Dept. of Physics*	NTNU
	Børge Damsgård, *Managing Director*	UNIS
	Grete K. Ersland, *Head of Admin., Secretary, IFT Board*	UiB

Technical and Administrative Team

Arve Aksnes, *Advisor*	M	UiB
Georgi Genov, *Senior Eng.*	M	UiB
Thomas Poulianitis, *Chief Eng.*	M	UiB
Nuno Roque, *Staff Eng.*	M	UiB
Maja Rostad, *Chief Eng.*	F	UiB
Mikko Syrjäsuo, *Head Eng.*	M	UNIS
Shiming Yang, *Senior Eng.*	M	UiB
Kavitha Østgaard, *Sr. Consultant*	F	UiB

Scientific Team

Lisa Baddeley	Assoc. Professor	F	UNIS
Patrick Espy	Professor	M	NTNU
Jesper Gjerloev	Professor II	M	UiB
Robert Hibbins	Professor	M	NTNU
Dag Lorentzen	Professor	M	UNIS
Martino Marisaldi	Assoc. Professor	M	UiB
Stephen Milan	Professor II	M	UiB
Kjellmar Oksavik	Professor	M	UiB
Kjartan Olafsson	Assoc. Professor	M	UiB
Noora Partamies	Assoc. Professor	F	UNIS
Fred Signernes	Professor	M	UNIS
Johan Stadsnes	Professor *Emeritus*	M	UiB
Finn Søraas	Professor *Emeritus*	M	UiB
Kjetil Ullaland	Professor	M	UiB
Nikolai Østgaard	Professor	M	UiB
Brant Carlson	Researcher II	M	UiB
Stein Haaland	Researcher II	M	UiB
Spencer Mark Hatch	Researcher *(from 9/2020)*	M	UiB
Pavlo Kochkin	Researcher	M	UiB
Karl Magnus Laundal	Researcher	M	UiB
Nikolai Lehtinen	Researcher	M	UiB
Andrey Mezentsev	Researcher	M	UiB
Yvan Orsolini	Researcher II	M	UiB
David Sarria	Researcher *(from 11/2020)*	M	UiB
Christine Smith-Johnsen	Researcher	F	UiB
Hilde Nesse Tyssøy	Researcher	F	UiB
Stefan Bender	Postdoc	M	NTNU
Lindis Bjoland	Postdoc	F	UNIS
Spencer Mark Hatch	Postdoc *(till 8/2020)*	M	UiB
Ville Aleksi Maliniemi	Postdoc	M	UiB
Anders Ohma	Postdoc	M	UiB
Jone Petter Reistad	Postdoc	M	UiB
David Sarria	Postdoc *(till 10/2020)*	M	UiB
Kjetil Albrechtsen	PhD candidate	M	UiB
Eldho Midhun Babu	PhD candidate	M	UiB
Ingrid Bjørge-Engeland	PhD candidate	F	UiB
Margot Decotte	PhD candidate	F	UiB
Jone Øvertvedt Edvartsen	PhD candidate	M	UiB
Reham Elhawary	PhD candidate	F	UiB
Nina Kristine Eriksen	PhD candidate	F	UNIS
Sara Gasparini	PhD candidate	F	UiB
Katie Herlingshaw	PhD candidate	F	UNIS
Anders Lindanger	PhD candidate	M	UiB
Michael Madelaire	PhD candidate	M	UiB
Carolina Maiorana	PhD candidate	F	UiB
Josephine Salice	PhD candidate	F	UiB
Chris A. Skeie	PhD candidate	M	UiB
Fasil Tesema	PhD candidate	M	UNIS
Wim van Caspel	PhD candidate	M	NTNU

MAJOR ACHIEVEMENTS

December 2020	**New spacecraft mission:** NASA selects the EZIE mission to study electric currents in Earth's atmosphere that link aurora to the Earth's magnetosphere. Launch is scheduled for 2024. Jesper Gjerloev is the Project Scientist for the EZIE mission, which he leads together with PI Sam Yee at APL, Johns Hopkins University. Karl Magnus Laundal is Co-I and Lead for Current Inversions. Also involved in the EZIE science team is Professor Patrick Espy of NTNU, who has a role as collaborator.
August 2020	**Easy access to research data:** To promote easy access to research data, BCSS (Kjellmar Oksavik) publishes The University of Bergen Global Navigation Satellite System Data Collection in the repository DataverseNO. The collection contains data from four global navigation satellite system receivers at four locations (Ny-Ålesund, Longyearbyen, Hopen, Bjørnøya).
July 2020	**Kick-off for TMS Starting Grant :** In 2019, Karl M. Laundal won the annual Trond Mohn Foundation (TMS) Starting Grant. His winning proposal was entitled "What Shapes Shape." The project is initiated in July, 2020.
June 2020	**Mission extension:** The ASIM mission, originally intended to last for two years (ending in the summer of 2020), is extended through 2021.
May 2020	**TV interview:** TV2 interviews BCSS Leader Nikolai Østgaard regarding the ASIM launch in 2018 in connection with a live report on launch preparations for the first NASA manned launch since 2011. The interview focuses on the ASIM launch to the Columbus module of the International Space Station and subsequent commissioning of the instrument.
April 2020	**Gamma-ray observations from space:** On April 15, ASIM observes gamma-ray bursts from a type of neutron star known as magnetar, located in a distant galaxy. While other platforms also observe the gamma-ray bursts, the quality of the ASIM measurements are considered the highest. Link to official statement about the findings. **Historic spacecraft milestone:** The Cluster mission–originally intended to be a 2-year mission–celebrates 20 years in space. The space physics group at the University of Bergen (known today as the Birkeland Centre for Space Science) has played an important part throughout the life of the Cluster mission, building part of the RAPID instrument aboard Cluster, as well as performing data analysis. As Cluster heads into its third decade, exciting new research results keep coming, with BCSS-researchers playing a central role.
January 2020	**Cover page:** The paper by Neubert and Østgaard et al. (2020) on the discovery of gamma ray flashes from ASIM is featured on the cover page of *Science*. **Media coverage:** The recent ASIM findings regarding gamma ray flashes from thunderstorms is covered by 100 news articles in media all over the world. **TV Interview:** Fred Sigernes appears in Episode 1 of the NRK program called "Snowhow: The Nordic Winter". He gives a tour of the Kjell Henriksen Observatory (KHO) at UNIS, which houses over 25 optical instruments.

PUBLICATIONS

1. **J.P. Reistad, K.M. Laundal, A. Ohma**, T. Moretto, S.E. Milan (2020), An explicit IMF By dependence on solar wind–magnetosphere coupling, *Geophys. Res. Ltr.,* doi: 10.1029/2019GL086062

2. **S. Haaland**, P.W. Daly, E. Vilenius, P. Krcelic, I. Dandouras (2020), Suprathermal Fe in the Earth's Plasma Environment: Cluster RAPID Observations, *J. Geophys. Res.: Space Physics,* doi: 10.1029/2019JA027596

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