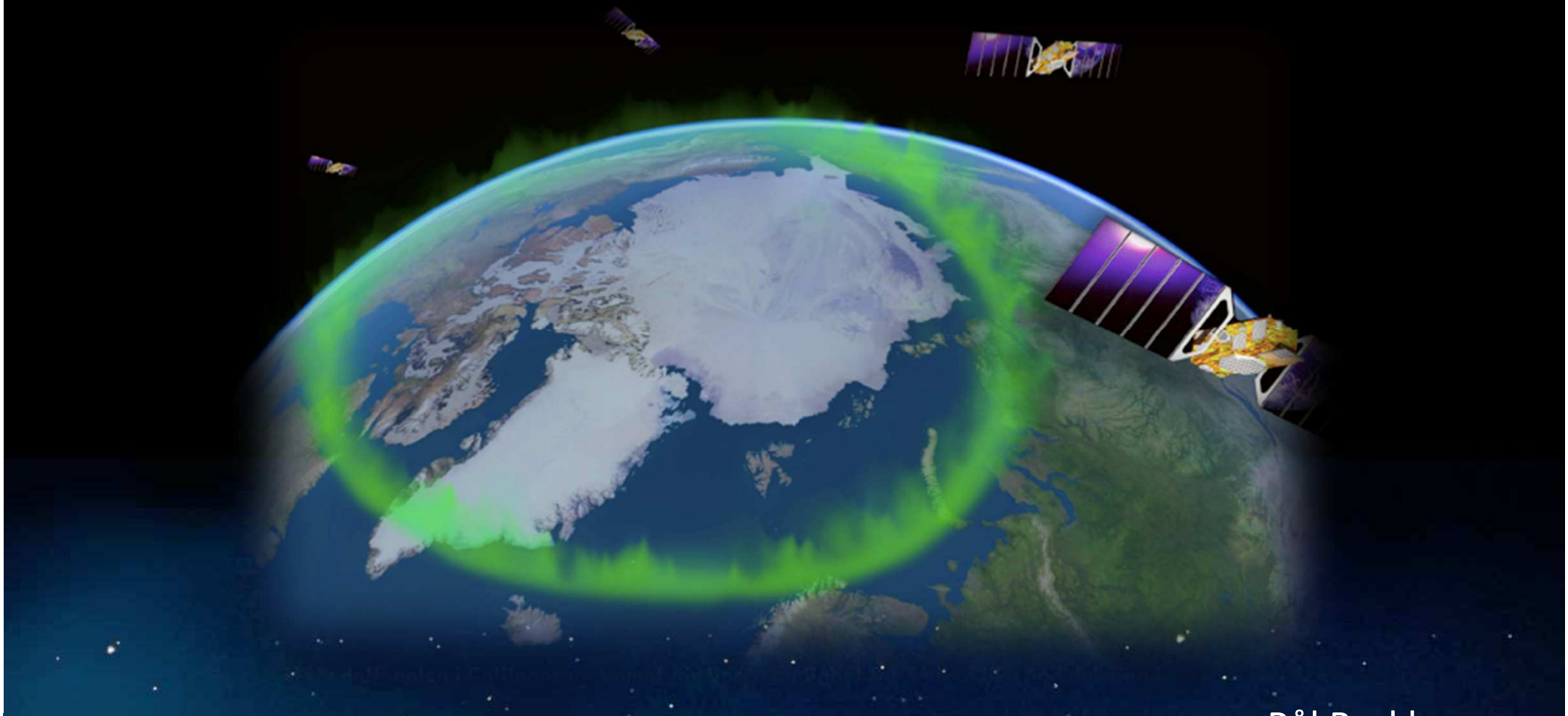
Space Weather Effects on Critical Operations and Activity in the High North



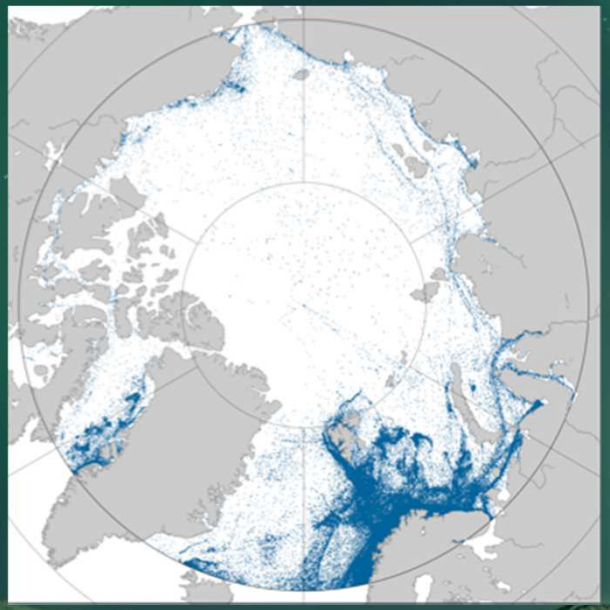
Pål Brekke
Senior Advisor
Paal@spacecentre.no

Norsk Romsenter
NORWEGIAN SPACE CENTRE

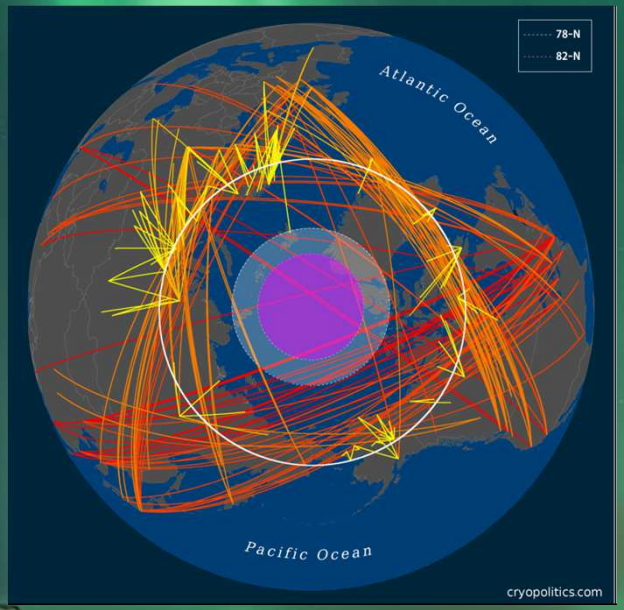
ISWI Workshop, Boston College, 31 July - 4 August 2017

Space Weather in the Arctic

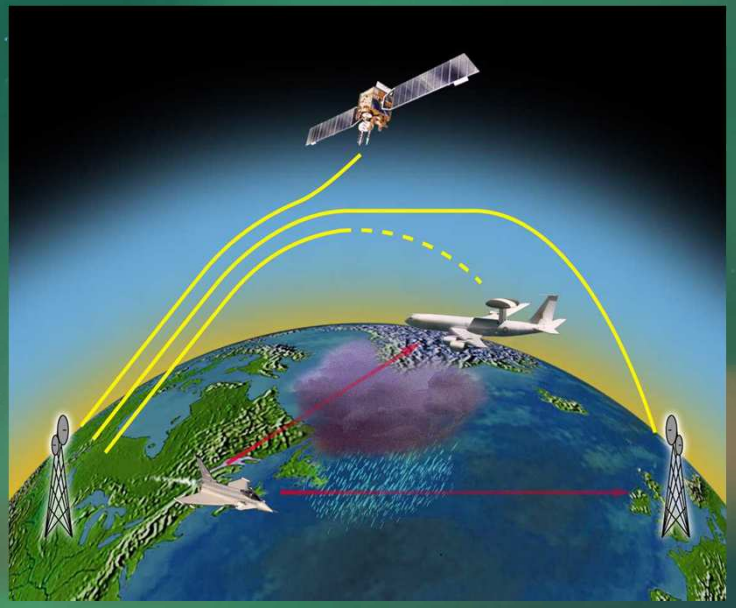
Space weather see no national boundaries - but in the Arctic there are some different challenges



Ship traffic from AisSat-1



Polar flights

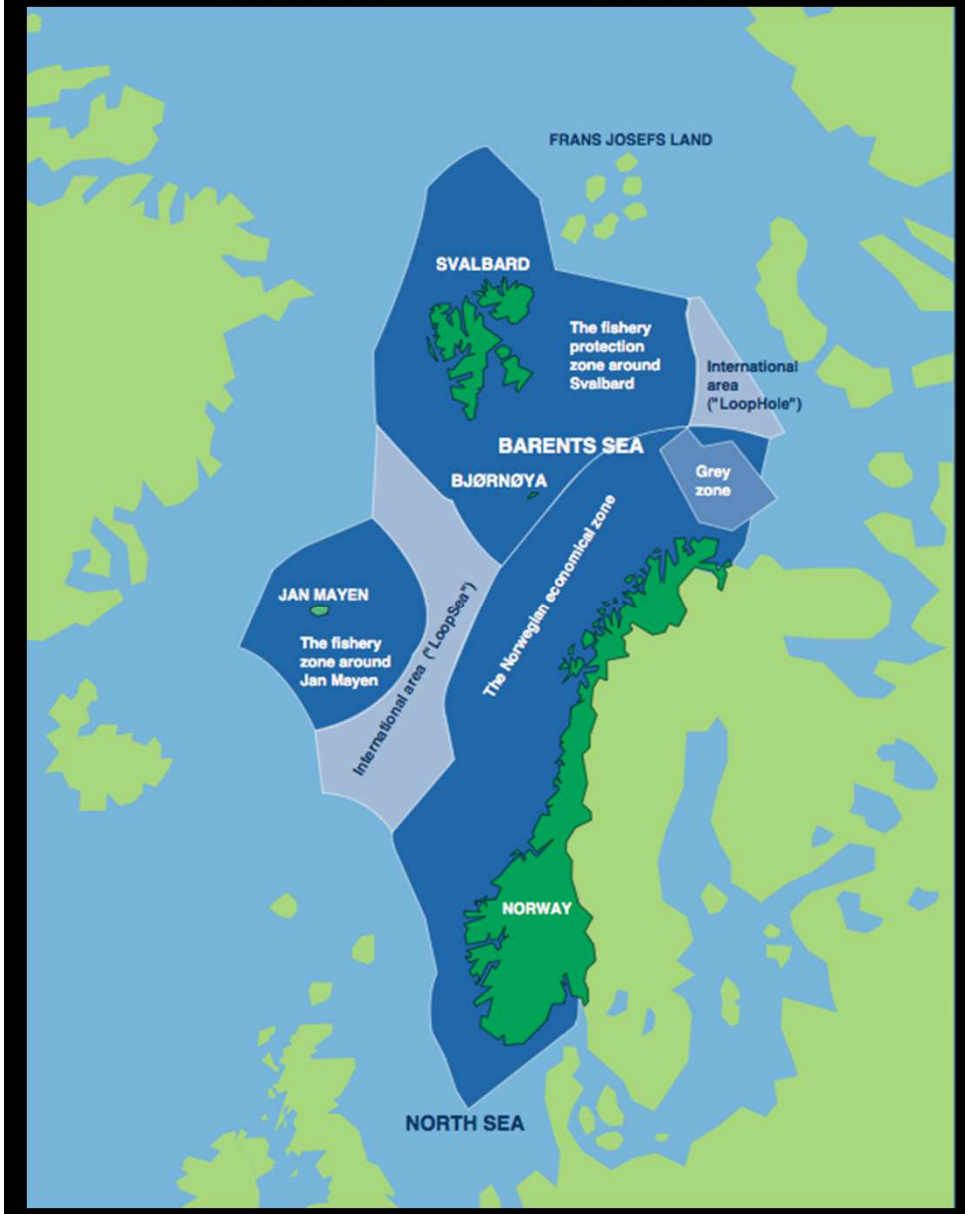


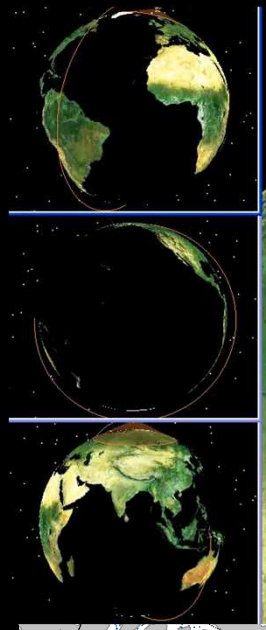
Radiocommunication

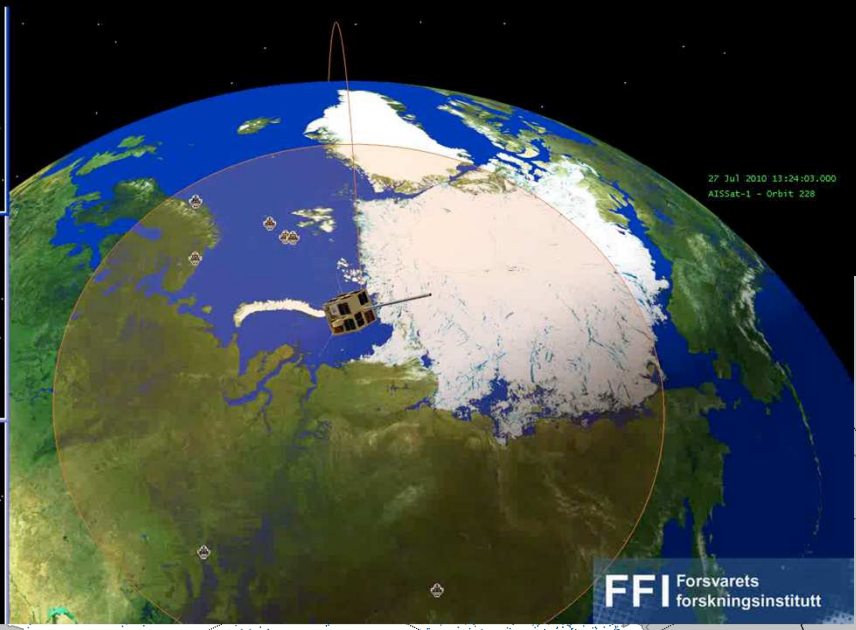
With increases activity in the Arctic region space weather will be an important part of Norway's role to ensure both safe navigation and good communication in these areas.

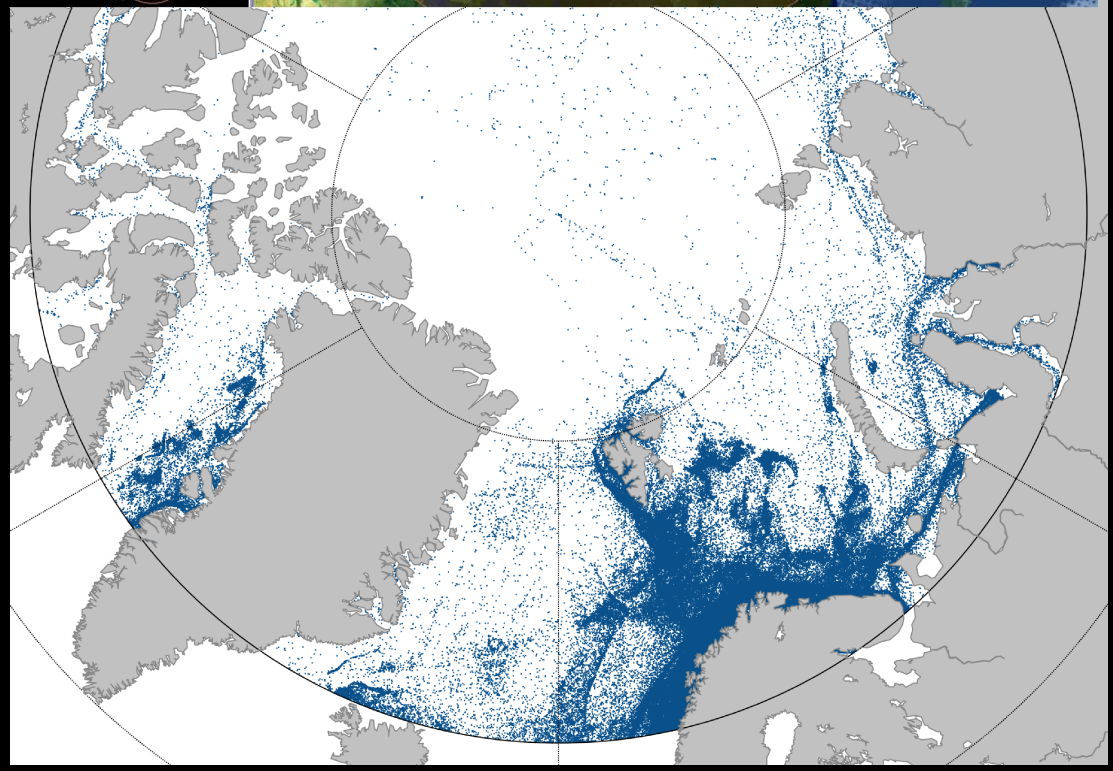
The need for reliable space weather forecast of high quality is necessary and highly wanted among Norwegian users.

The Norwegian Territory









Space Weather in the Arctic

Norway has

- operative demands
- interesting space weather infrastructure.
- several research groups on space weather (UiO, UiB, UiT, UNIS etc.)

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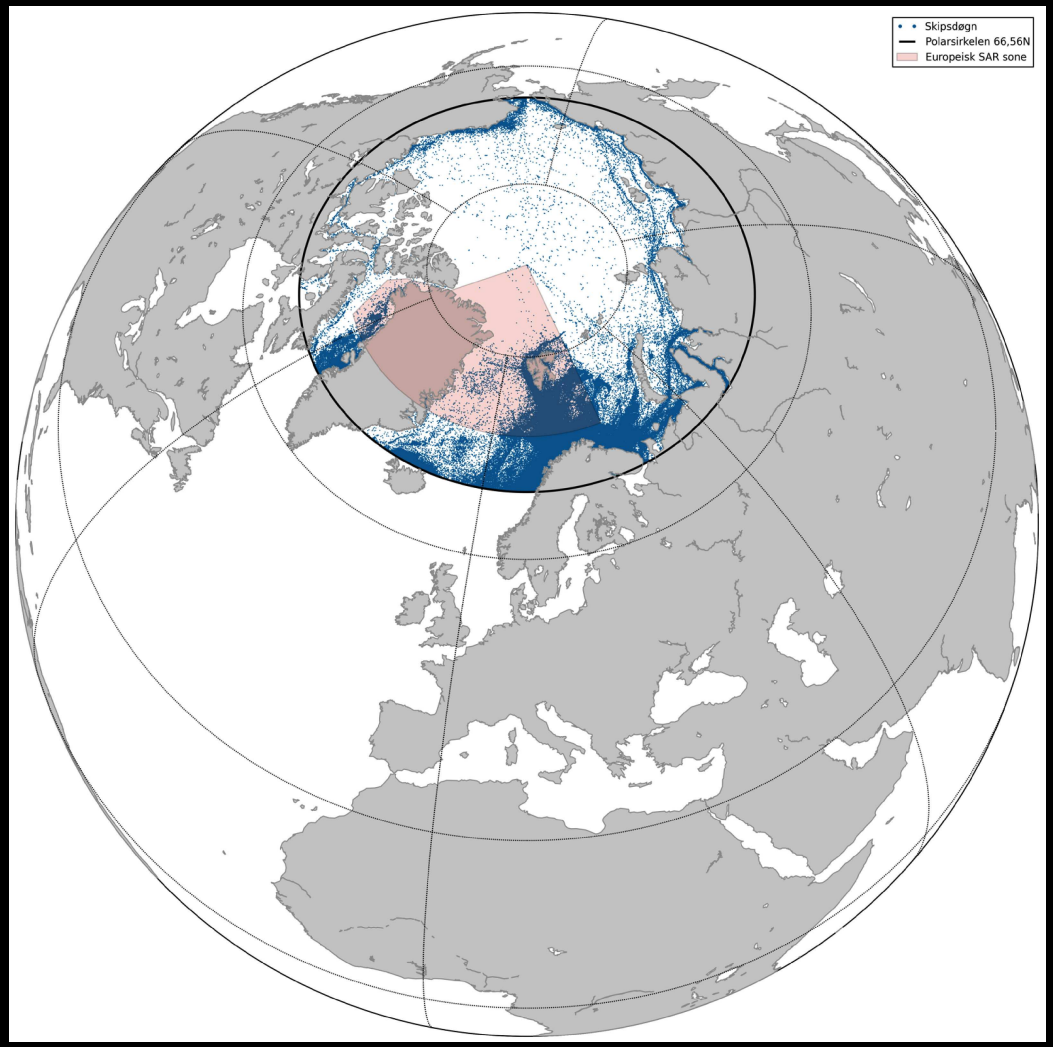
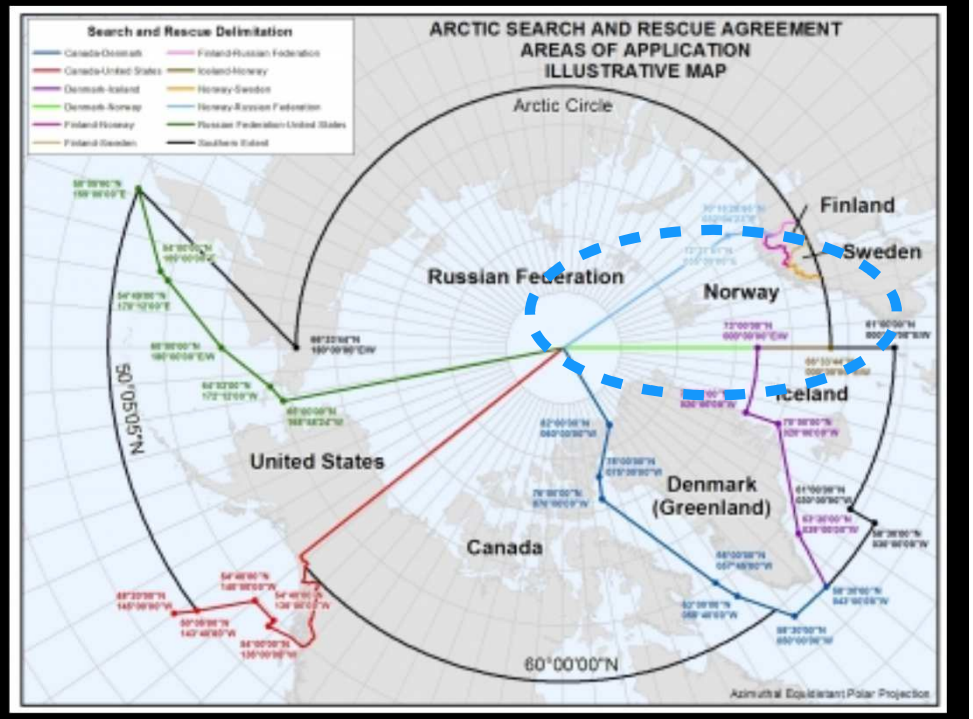
Search & Rescue in the Arctic





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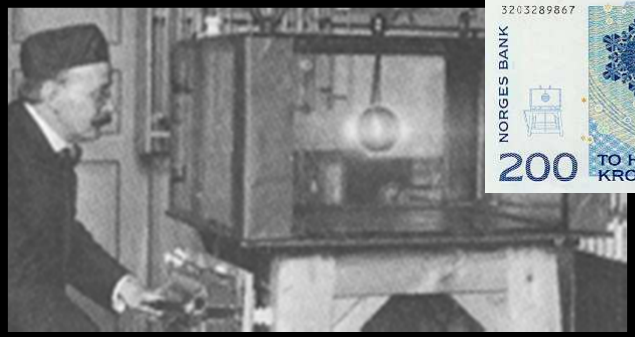
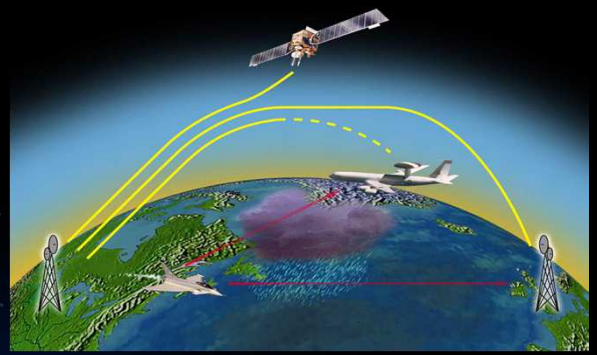
Long Traditions



Long traditions in space research - due to its northern location

- Observations of the Aurora before 1900
- Birkelands innovating aurora experiment (1886)
- National solar observatory in 1950.
- First launch of an aurora research rocket (1962)
- Early concerns about effects on military radio communication



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BIRKELAND CENTRE
FOR SPACE SCIENCE

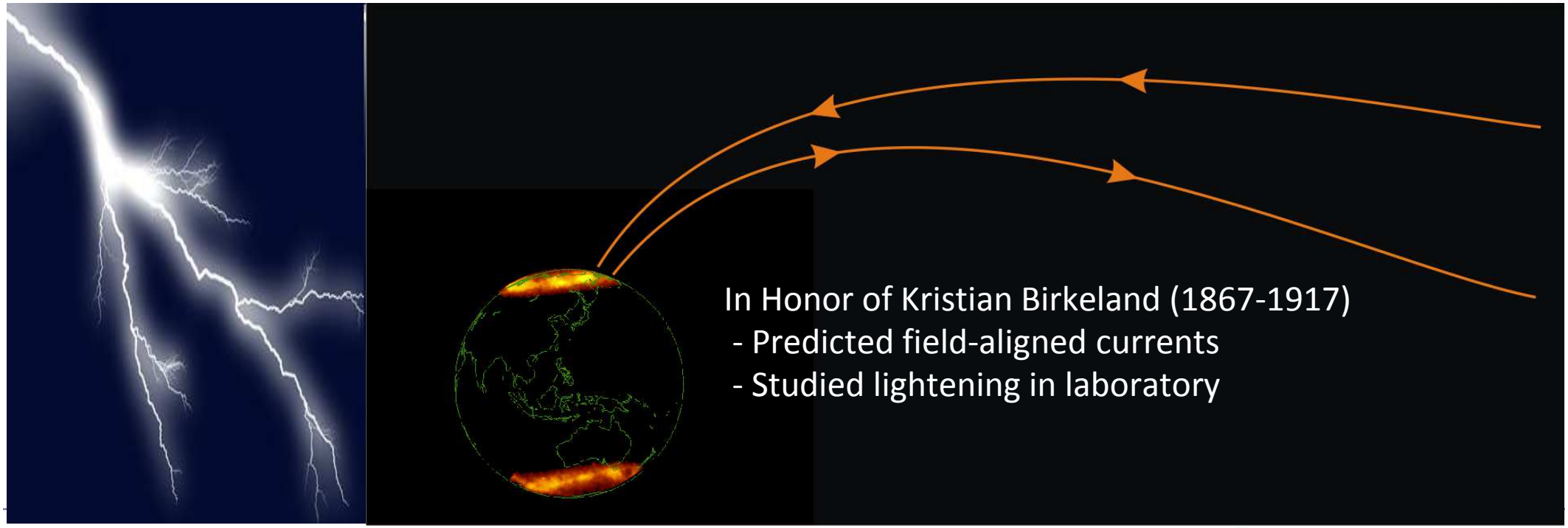
Birkeland Centre for Space Science

How Earth is coupled to space

Birkeland Centre for Space Science (BCSS) is a Centre of Excellence (CoE) at the University of Bergen (UiB), that also includes scientists from NTNU and UNIS.

PI: N. Østgaard

(UiB)



Talk by Karl Laundal (UiB) - Thursday at 0945.

UNIS
The University Centre in Svalbard

NTNU
Det skapende universitet

ANDØYA SPACE CENTER

The Cost Effective Entrance to Space

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Launches

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World
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Feedback
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Help

Thursday, January 21, 1999 Published at 19:12 GMT

Sci/Tech

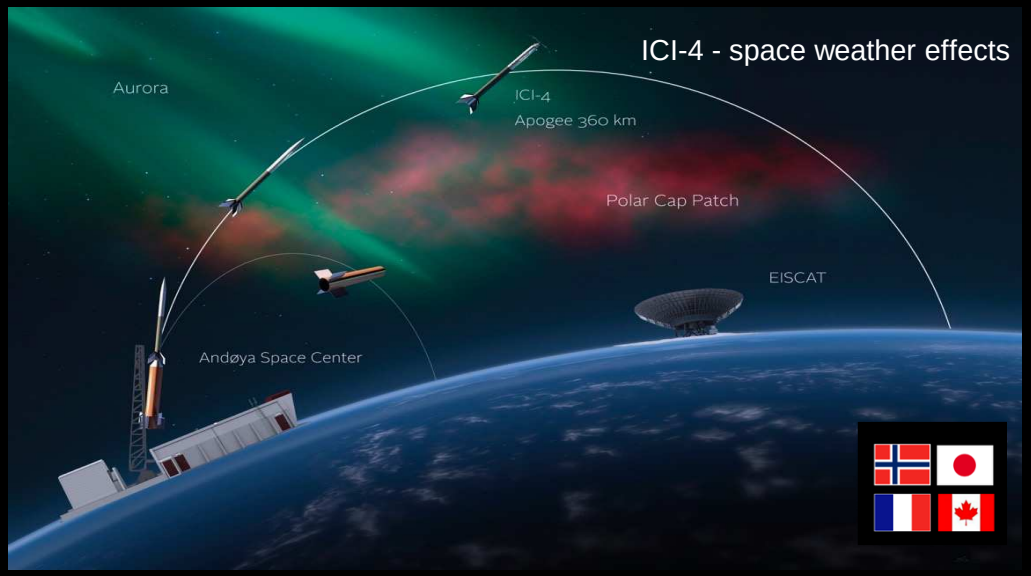
Successful Caper in Norway

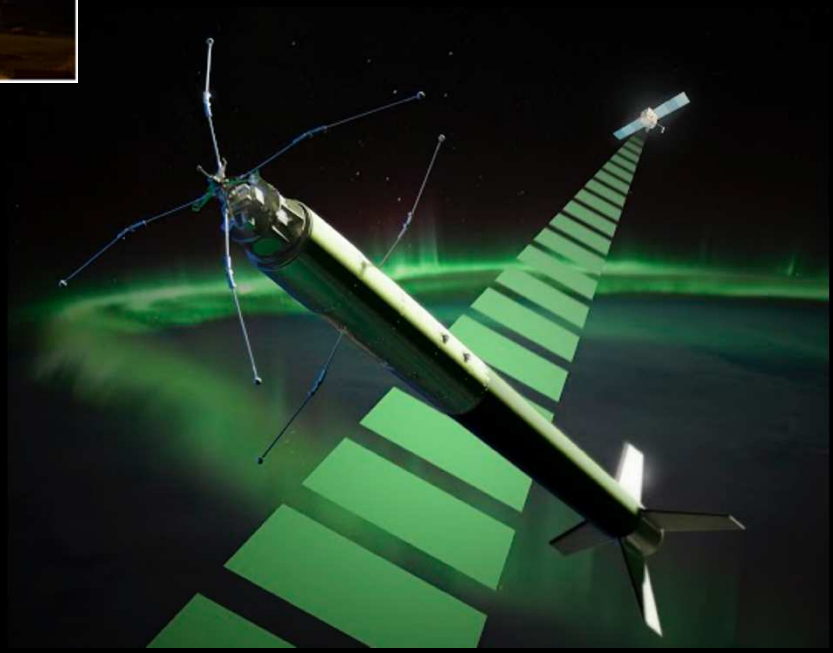
Poor conditions had delayed the launch

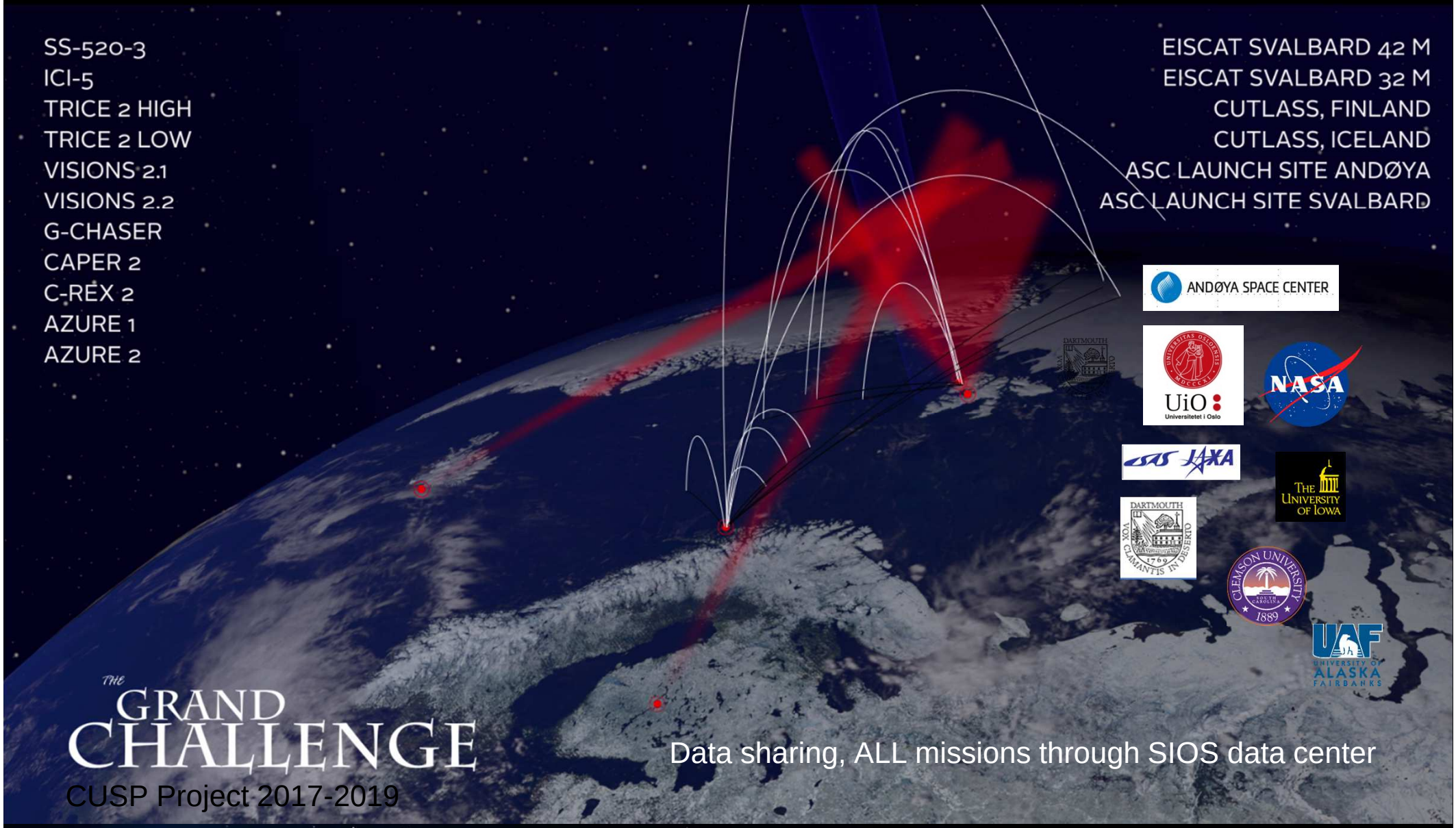
A rocket designed to investigate the "space weather" responsible for the Northern Lights blasted off from a rocket range in Norway on Thursday.

The Caper (Cleft Accelerated Plasma Experimental Rocket) was part of a joint US-Norwegian research project.

Launch of the NASA Charged Aerosol Release Experiment (CARE II) from Andoya Space Center in Norway, Sept. 16, at 19:06 GMT. -







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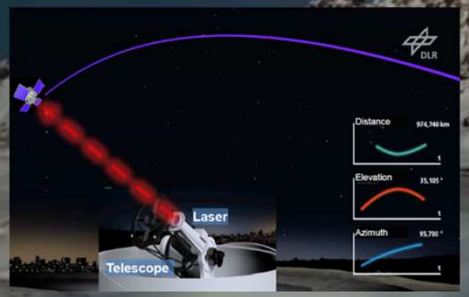
ALOMAR Observatory

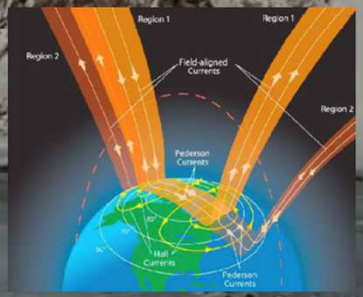
Arctic Lidar Observatory for Middle Atmosphere Research

International atmospheric observatory;

Norway, Germany, USA, Bulgaria, UK, Canada, Spain, France, Switzerland

- Operating since 1994
- 4 day/night lidars: RMR, Fe, Ozone, Troposphere (covering 0 - 120km)
- 3 radars: MAARSY (MST), Saura MF, SKiYMET
- All systems operated by the ALOMAR staff
- 500 + publications in the 20 years of operation
- ALOMAR tropo-lidar: ADM-AEOLUS validation 2017 =>
  - Accepted by ESA
  - Operations funded by Norwegian Space Centre
- Ongoing work:
  - DLR Stuttgart to do optical tracking of space debris from Sept. 2018
  - Optically pumped magnetometer for investigations of Birkeland currents (MOM) by Tromsø Geophysical Inst. ~late 2018
-





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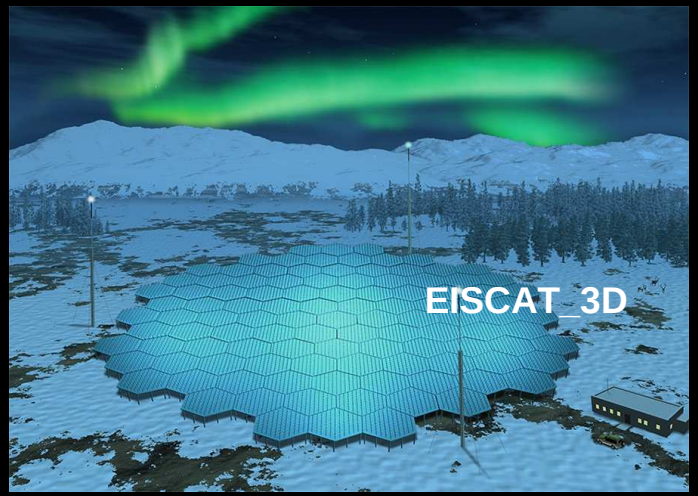
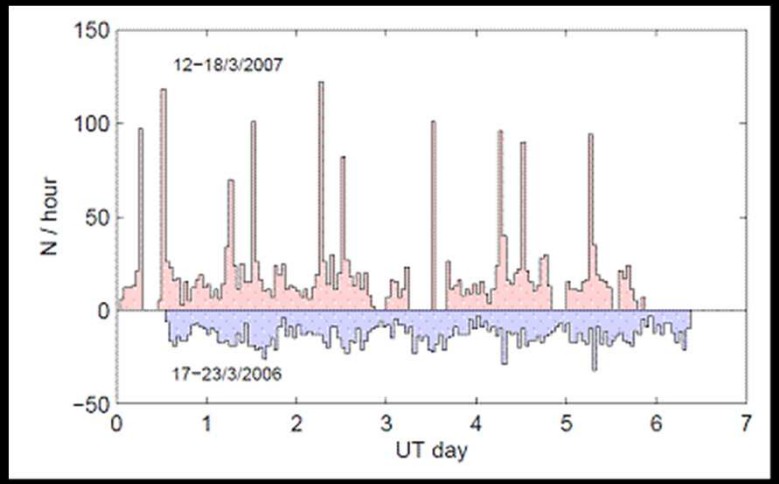
The EISCAT radars

EISCAT (European Incoherent Scatter) antennas in Norway, Sweden and Finland. Studies the interaction between the Sun and the Earth (ionosphere, plasma clouds etc.) Also useful for tracking space debris





Aurora Observatory at Svalbard
Kjell Henriksen Observatory

Rent a rom with a “view”

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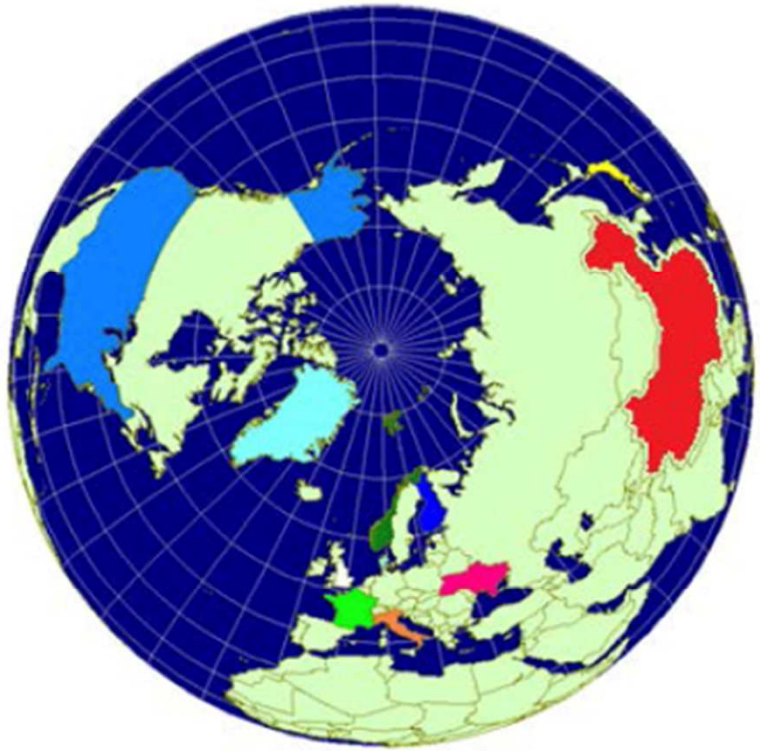
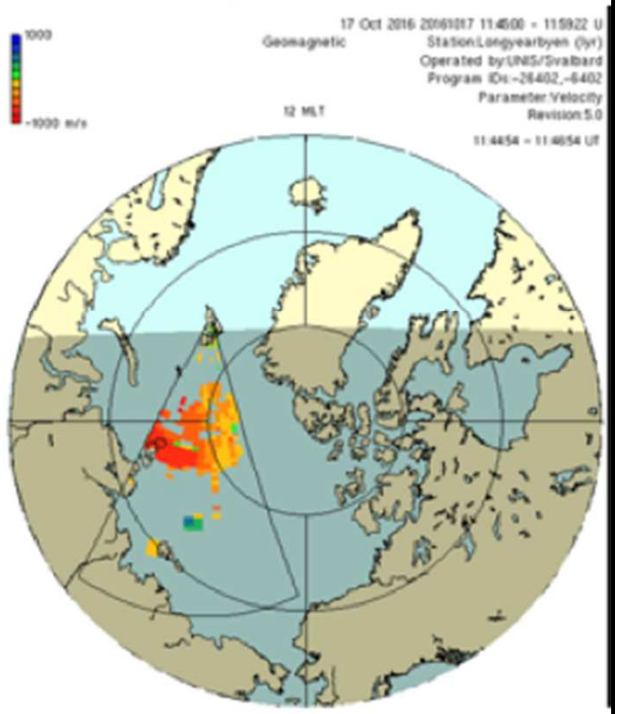
Institutions @ KHO

1. University Centre in Svalbard
2. University of Oslo
3. University of Tromsø
4. University of Alaska, Fairbanks
5. University College London
6. University of Wales Aberystwyth
7. University of Southampton
8. University of New Hampshire
9. Augsburg College
10. Tohoku University
11. National Institute of Polar Research Japa
12. Finnish Meteorological Institute
13. Embry Riddle Aeronautical University
14. Danish Meteorological Institute *
15. Air Force Research Laboratory *
16. Laboratoire de Planétologie de Grenoble
17. Institute of Radio Astronomy
18. AVINOR
19. The Polar Institute of China
20. The University of Electro-Communications Tokyo



The 10 Nations @ KHO

… & excellent students!

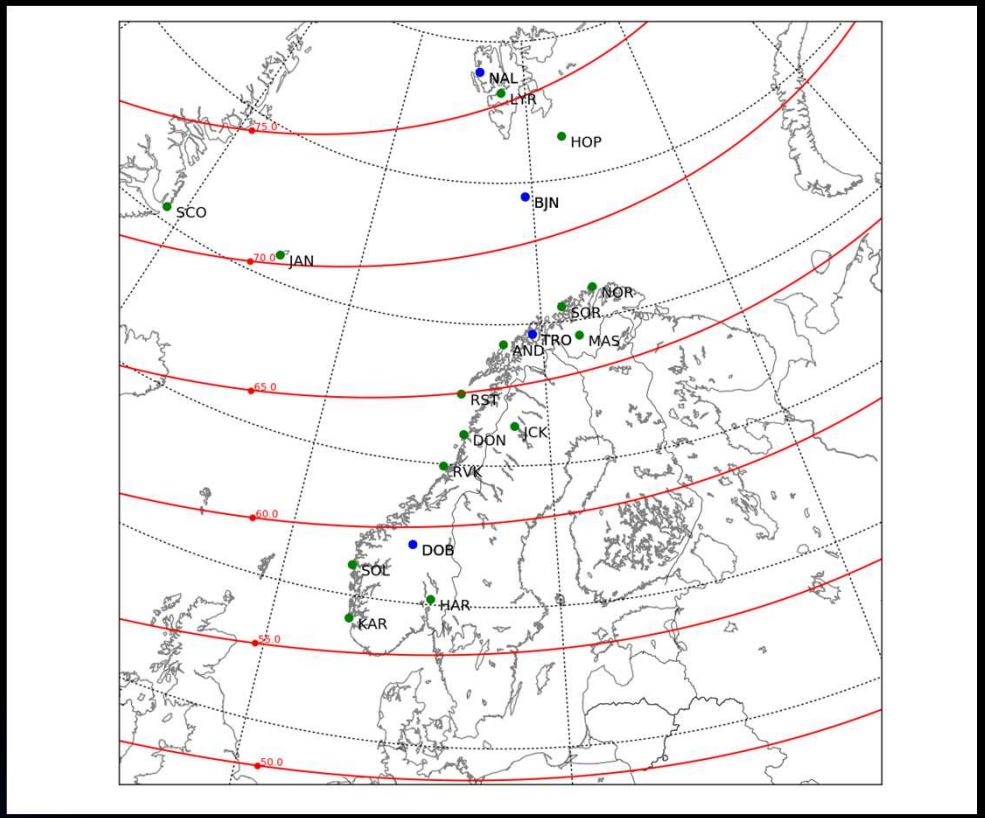


The Svalbard SuperDARN radar

- **Principal Investigator:** Prof. Dag A. Lorentzen, UNIS and The Birkeland Centre for Space Science (BCSS).
- **Co-Investigator:** Assoc. Prof. Lisa Baddeley, UNIS and BCSS,
- **Project Scientists:** Prof. Kjellmar Oksavik, Univ. of Bergen and BCSS
  Dr. Pål Brekke, Norwegian Space Centre and UNIS
  Prof. Jøran Moen, Univ. of Oslo and UNIS
  Prof. Fred Sigernes, UNIS and BCSS
- **Project engineer:** Dr. Mikko Syrjäsuo, UNIS and BCSS

Tromsø Geophysical Observatory (TGO)

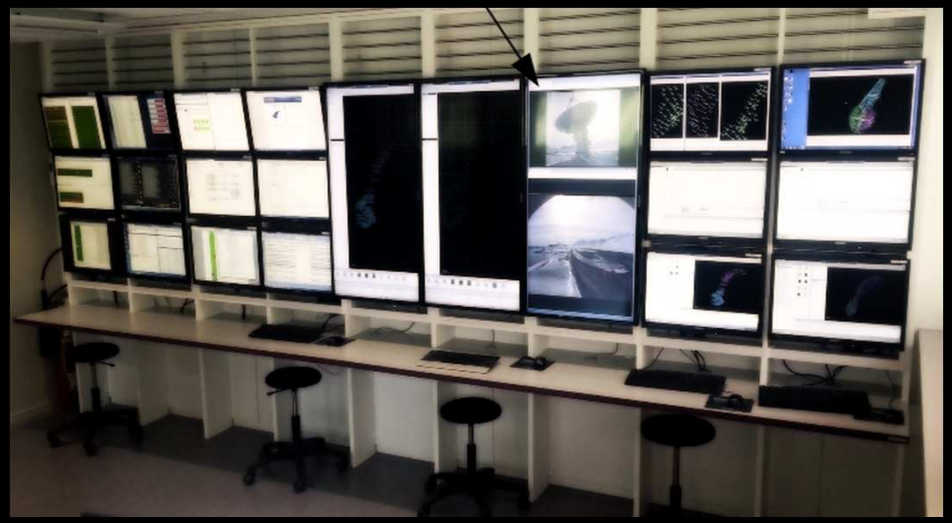
- Unit directly under the Faculty of Science and Technology at UiT
- Main Responsibility: Maintain observational time series (1928/32 – future) of the geomagnetic field in Norway (magnetometers) and electron density profile above Tromsø (ionosonde).
- Network off 14 magnetometers + other relevant systems.
- At present 8 employees (3 engineers, 5 scientists)

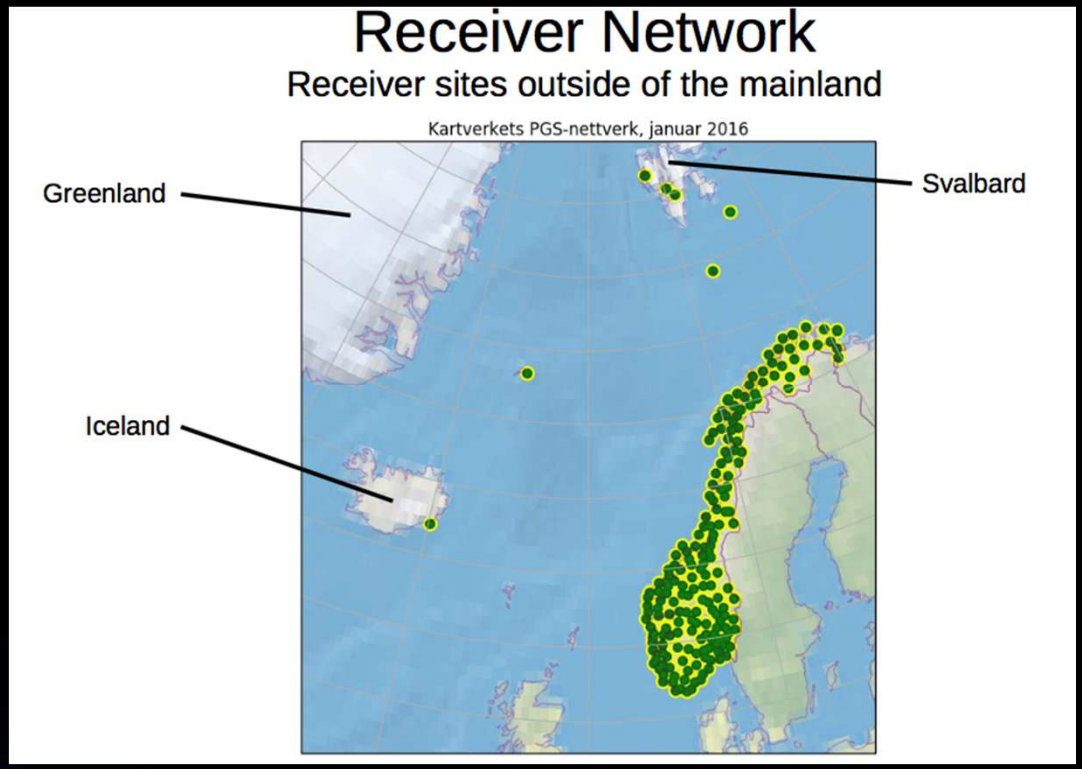


The Norwegian Mapping Authority

- Permanent Geodetic Stations on Norwegian Mainland and Svalbard
- The Norwegian Mapping Authority (NMA) has developed an ionospheric model based on the GNSS network.
- A network of 135 GNSS-receivers across Norway
- High ionospheric activity causes problems for calculating GPS-corrections in SATREF®

- SATREF® is a correction service they provide to the users





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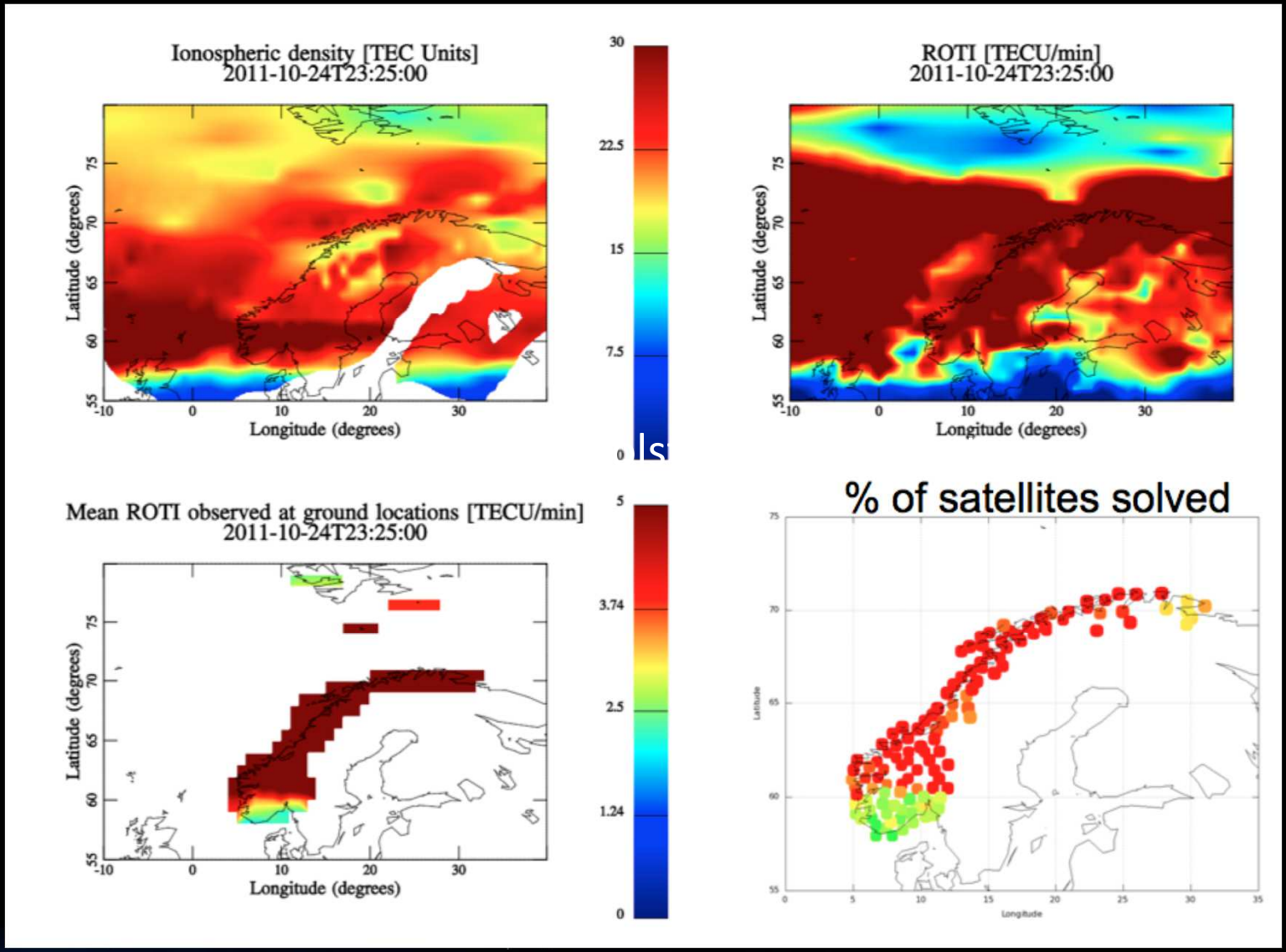
Solar storm effects on GPS



http://sesolstorm.kartverket.no

Ionosperic Monitoring Service for ESA SSA

esa space situational awareness

ESA SSA SWE NEO SST

About SWE
- What is Space Weather
- SSA Space Weather Activities
- Current Space Weather
- Contact

Service Domains
- Spacecraft Design
- Spacecraft Operation
- Human Space Flight
- Launch Operation
- Transionospheric Radio Link
- Space Surveillance and Tracking
- Power Systems Operation
- Airlines
- Resource Exploitation System Operation
- Pipeline Operation
- Auroral Tourism Sector
- General Data Service

Expert Service Centres
- ESC Solar Weather
- ESC Space Radiation
- ESC Ionospheric Weather
- ESC Geomagnetic Conditions
- ESC Heliospheric Weather

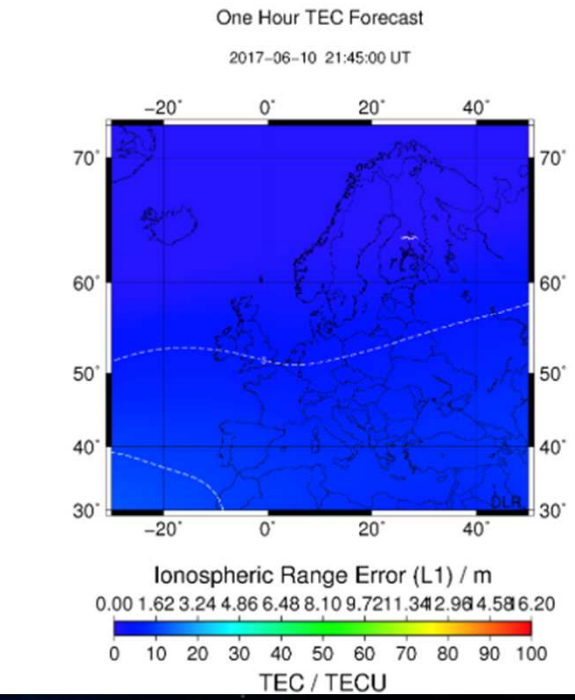
Other Resources
- Documents
- SWWT
- SWEN NewsLetter
- Upcoming Events

Sign-In
- You are not signed in.
- Sign In
- Request For Registration

Ionospheric Weather Expert Service Centre

This page provides access to the latest data, products and analysis tools from the SSA SWE Ionospheric Weather Expert Service Centre.

Latest data



ESC tools and products

IMPC
- TEC Europe and TEC Europe forecast
- TEC Global forecast
- Slab Thickness
- Scintillation Index
- ROTI maps for Europe

RTIM
- Plasma content above Nordic region
- Turbulence index over Nordic region
- Ground disturbances over Norway
- Scintillation map over Nordic region
- ROTI at ground time series (Selected locations in northern Europe)

EIS
- Integrated Electron Density Maps
- Current Ionospheric Conditions
- foF2 nowcast maps
- Long Term Prediction maps of foF2

RESOSS
- VTEC maps (Northern Europe)
- ROTI maps (Northern Europe)
- S4 and sigma-phi maps (Northern Europe)
- ROTI at ground time series (Selected locations in northern Europe)

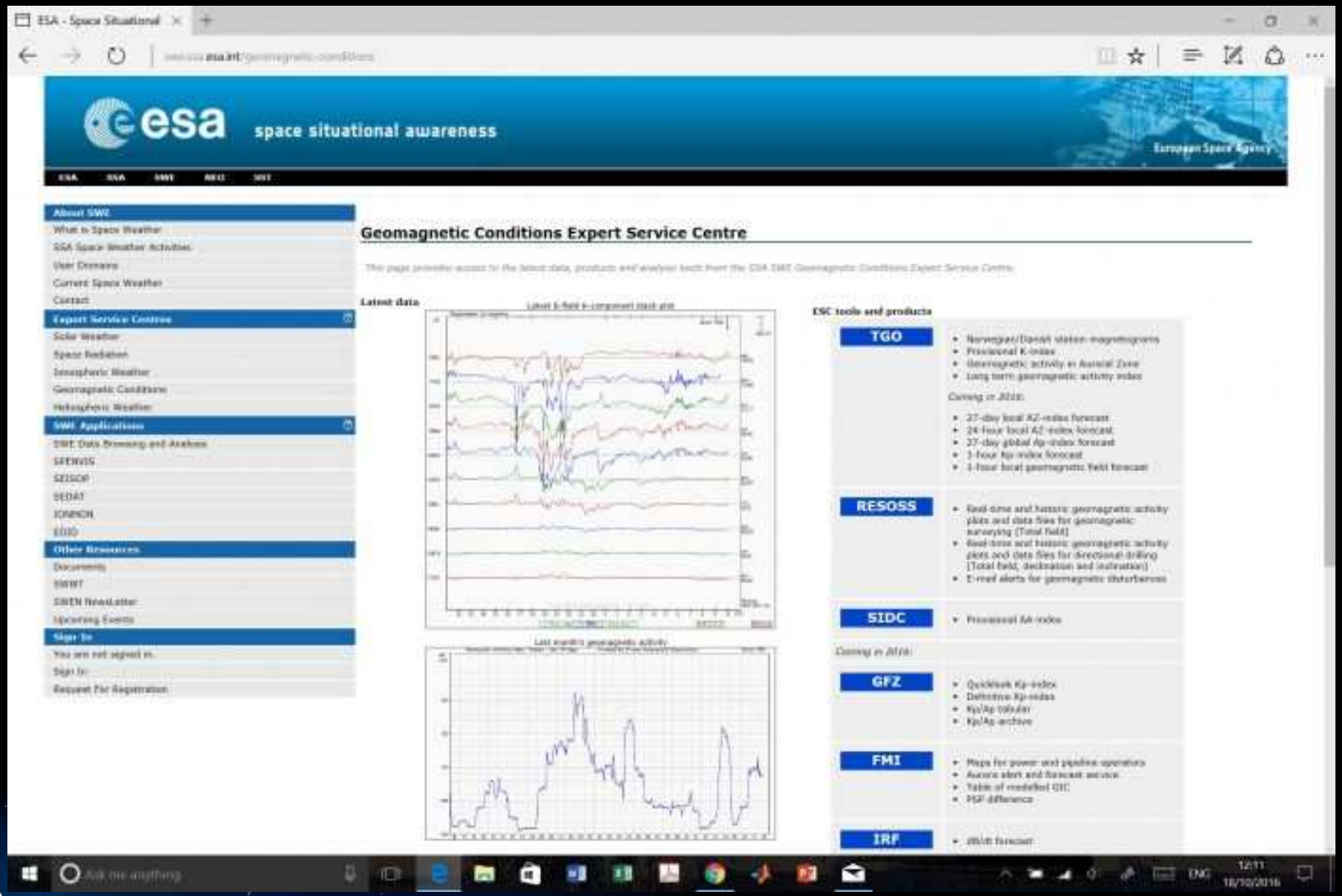
SISTED
- Sunlit Ionosphere Sudden TEC Enhancement Detector

GSFLAI
- GNSS Solar Flare Activity Indicator

SGIArv
- Archive of solar and geomagnetic indices for thermospheric drag calculation

Service supporting Resource Exploitation

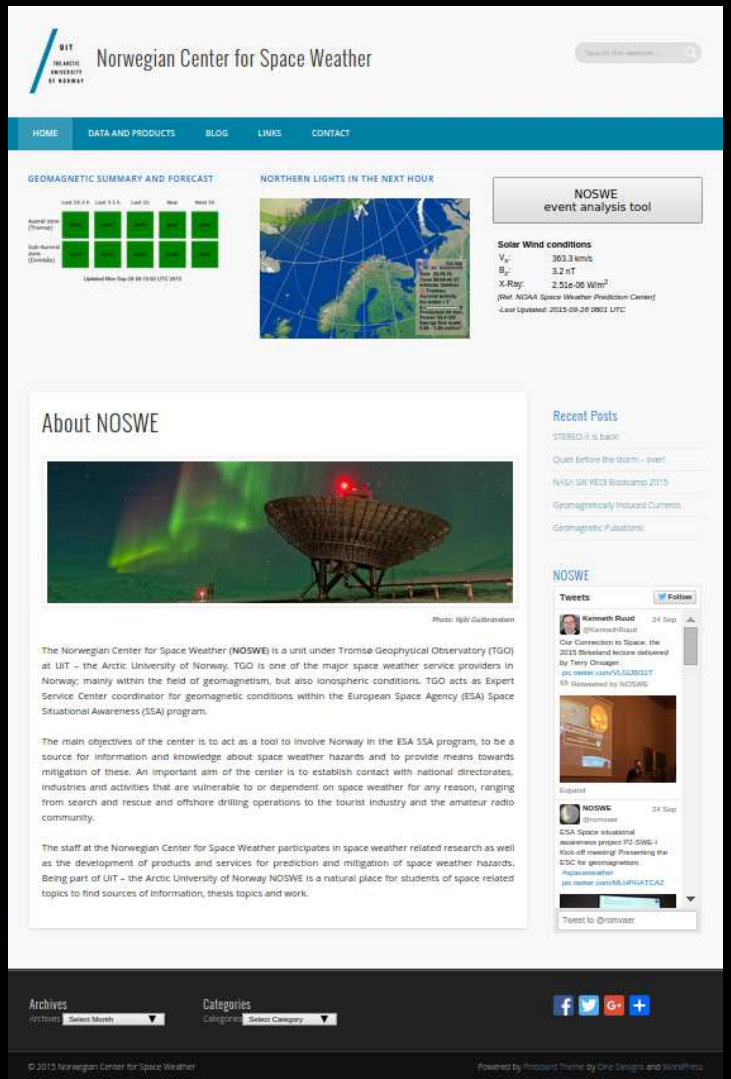
TGO and NMA



Norwegian Space Weather Center

Aim to get national responsibility for operational space weather acitivities.

Already planned emergency readiness with Norwegian Power Grid company (Statnett)
Will be built around a Space Weather monitoring center



We have initiated a collaboration with our national weather services (met.no) to distribute future space weather alerts/warnings.

http://site.uit.no/spaceweather/

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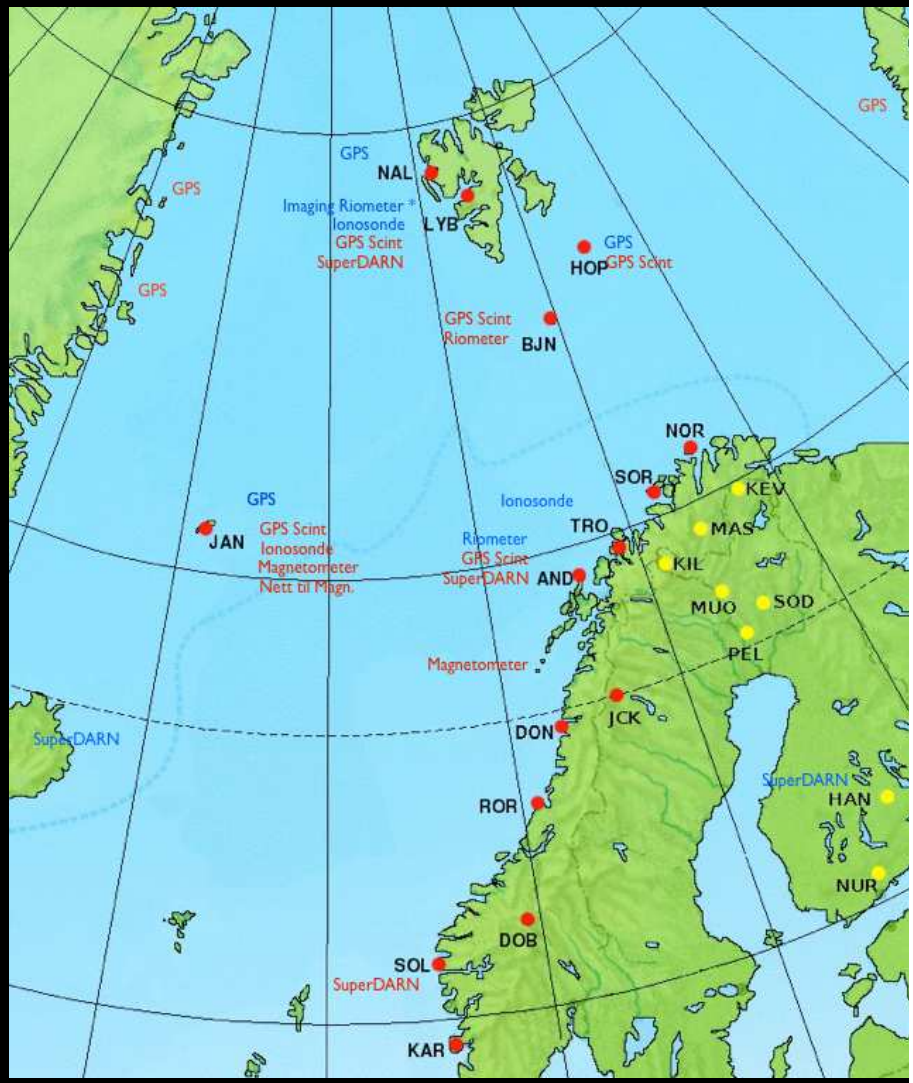
Infrastructure



NSC report 2012: Space Weather Infrastructure in Norway (V.L.Barth)

Conclusions: Norway, with its existing infrastructure can contribute in many areas in an European SW-service. The report also underline the need for upgrading some older systems as well as investing in new equipment.

Installing infrastructure on ships and platforms on the ocean.

In particular with infrastructure at Svalbard we have the best assumptions for detecting and forecasting disturbances on navigation systems in the Arctic.

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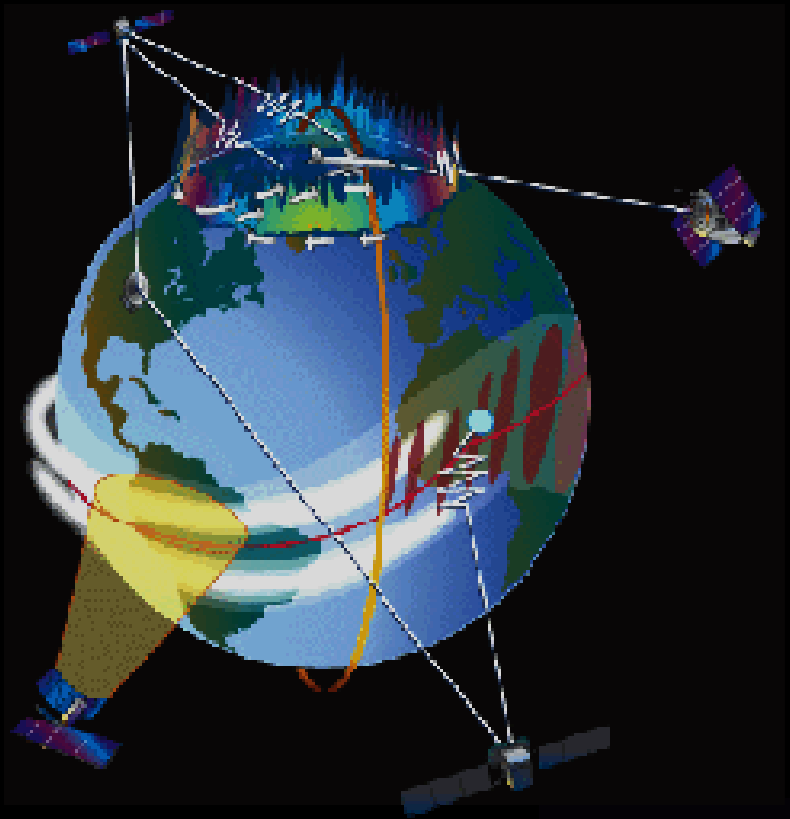
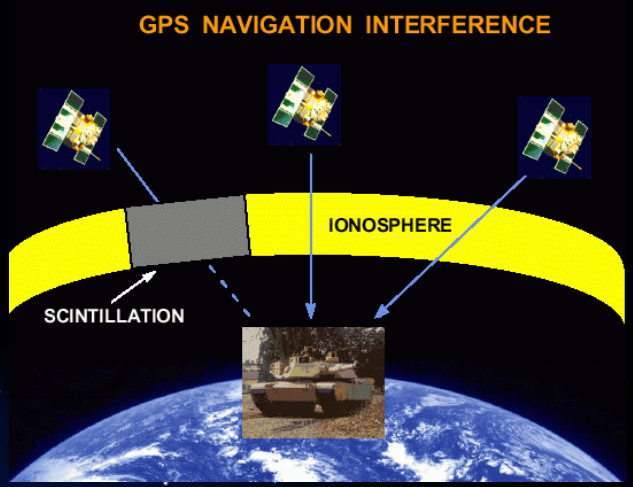
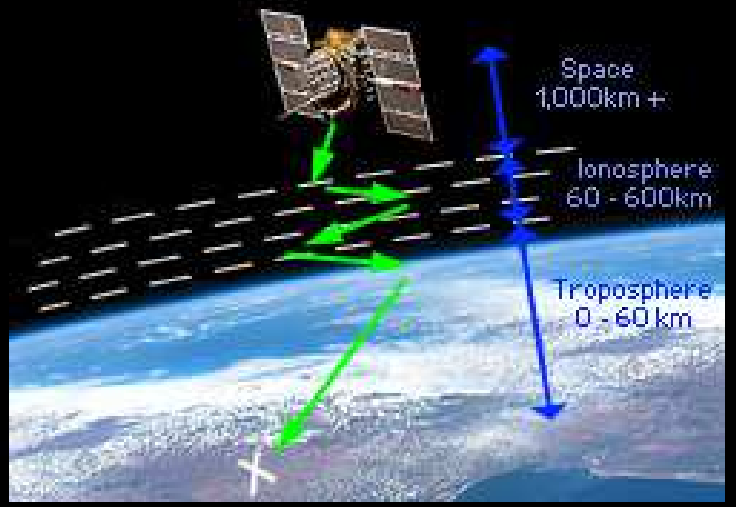
Navigation systems (GPS)



- Turbulence in the ionosphere causes scintillation in the satellite signal and can disrupt the reception.
- Total amount of electrons (TEC) along the path of the signal can introduce errors up to 100 meters.

- Radio bursts can «jam» the signals.





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Challenges in the Arctic

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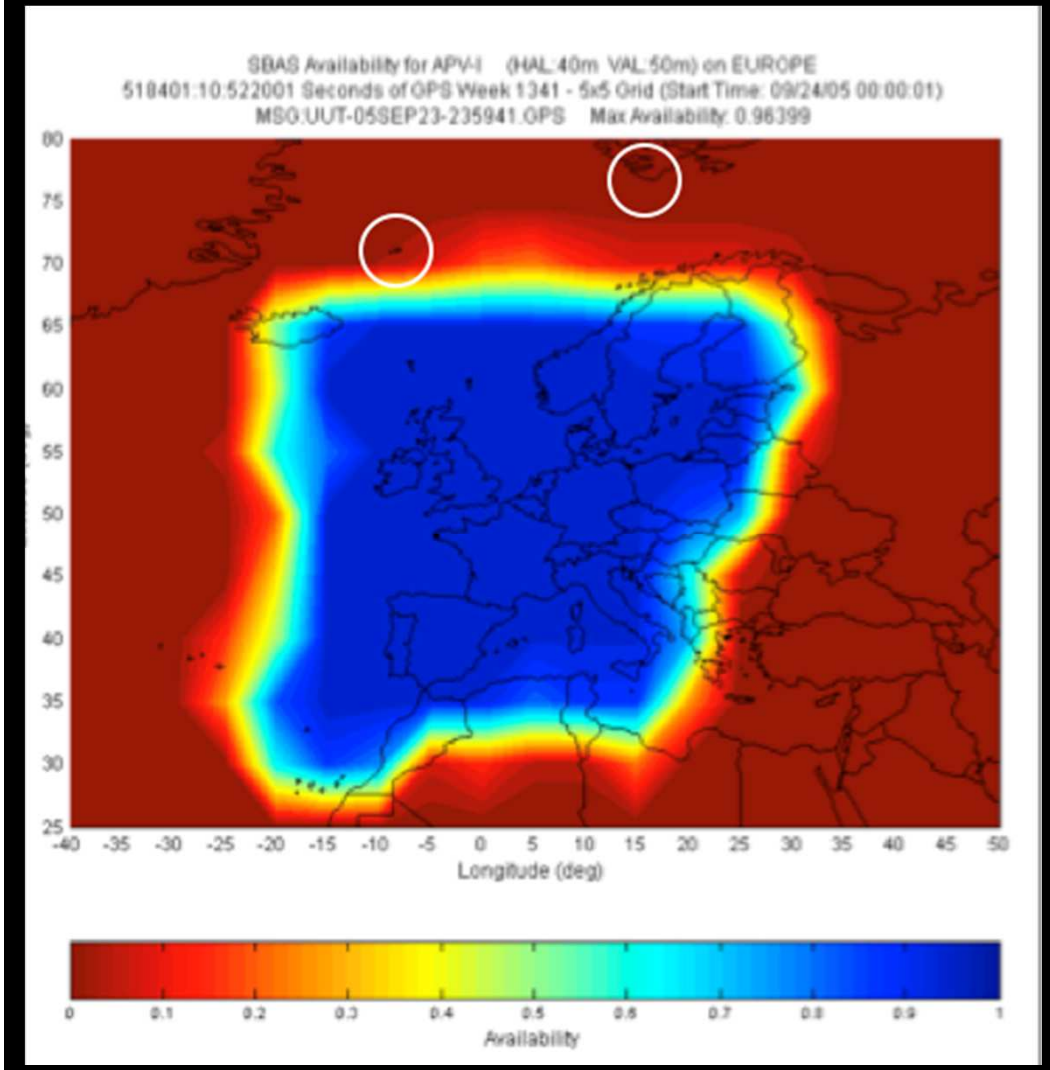
Limited EGNOS correction at high latitudes



- EGNOS provides corrections, but limited coverage far north.
- Two new EGNOS stations installed at Svalbard and Jan Mayen

- Another challenge: How will tracking of EGNOS signals via geostationary satellites work in the high north?

- These satellites are extremely low in the horizon and it is a challenge to decode data from them

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Some don´t care about GPS accuracy

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For others it is critical

- Errors in GPS based systems can be a serious problem.

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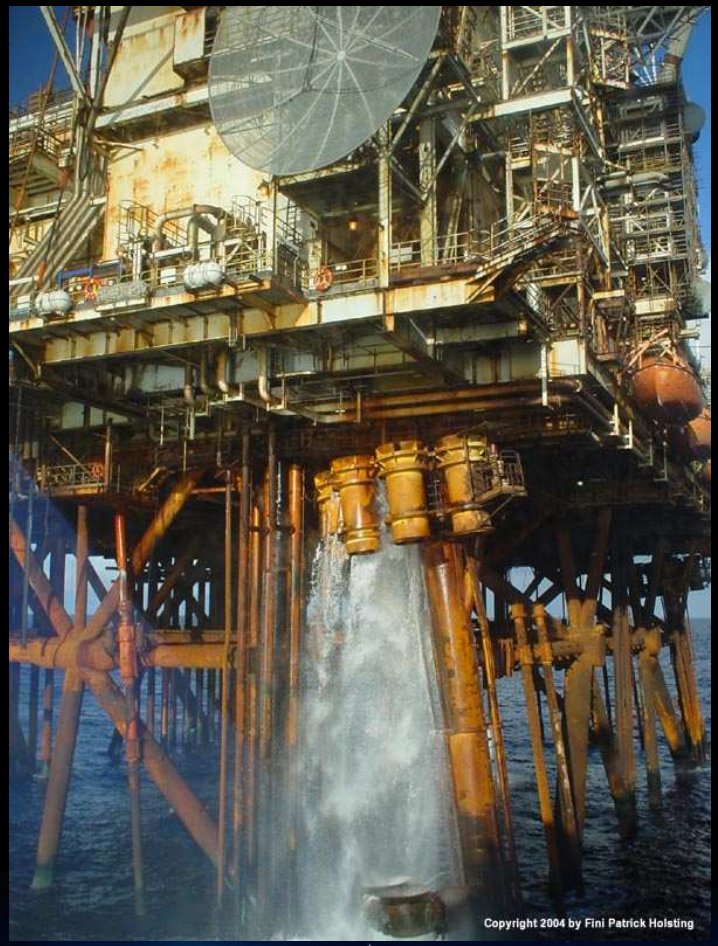
High precision positioning problematic

- Kongsberg Seatex - world leading within dynamical positioning. They experiences often disruption outside the coast of Brasil. This causes interruption of the operation.



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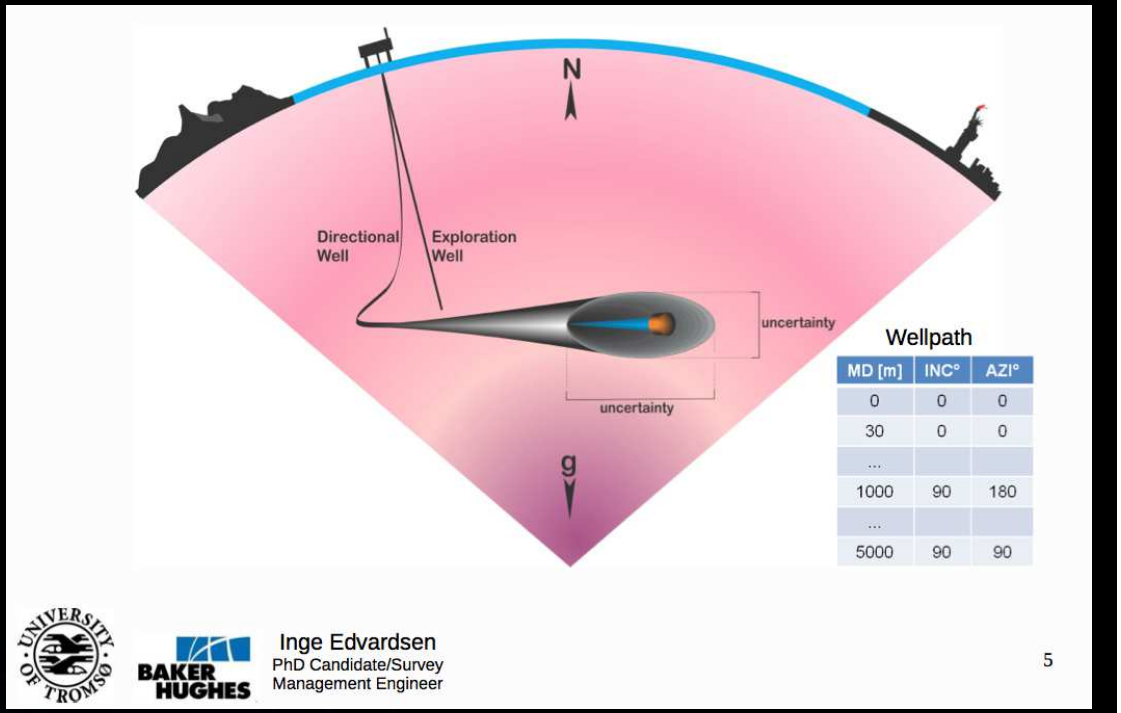
Directional drilling

Directional drilling

- Oil industry relies on geomagnetic maps to guide the drill and monitor the well direction.



Inge Edvardsen
PhD Candidate/Survey Management Engineer

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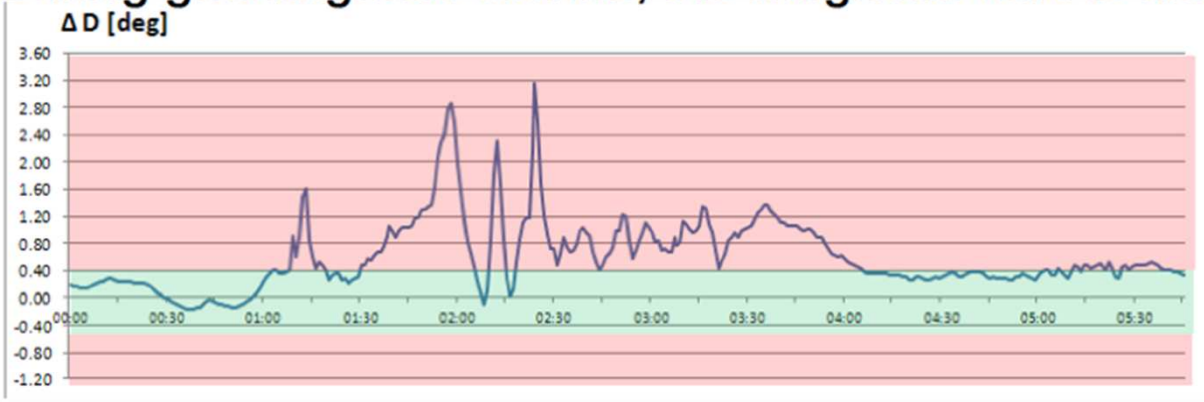
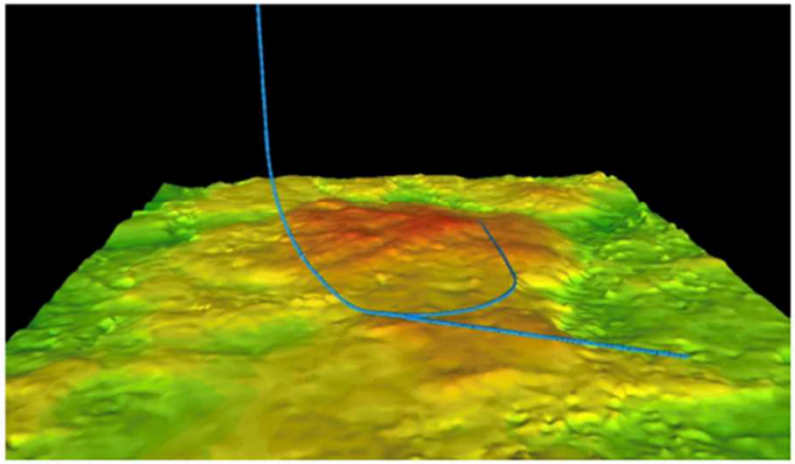
Directional drilling

During geomagnetic storms, the magnetic field is disturbed:

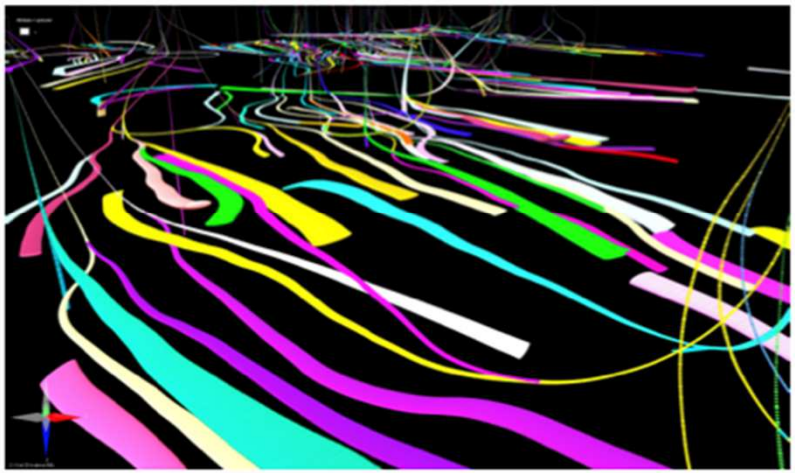


This has to be monitored and corrected for in order to:

Hit the Geological Target
(& maximize recovery)

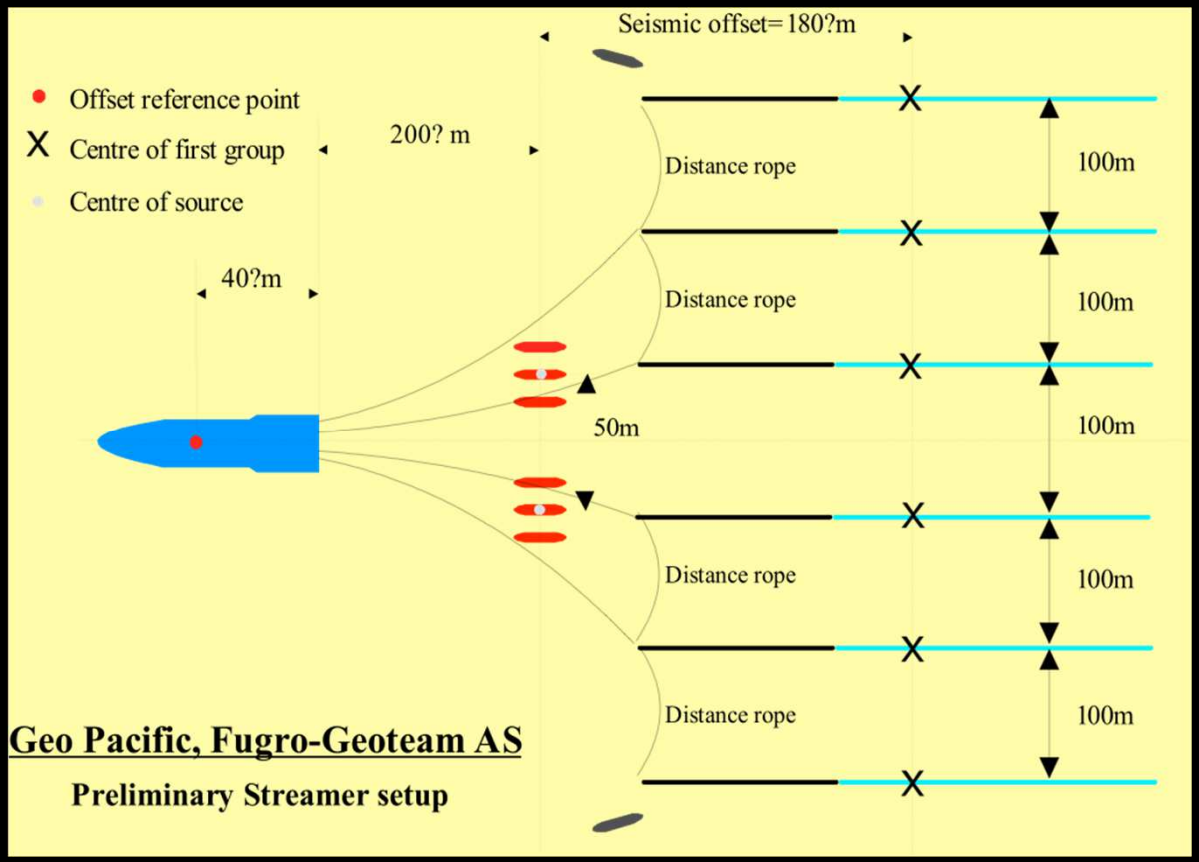


Avoid Other Wells



Inge Edvardsen
PhD Candidate/Survey
Management Engineer

Geomagnetic surveys - search for oil and gas



Fugro-Geoteam use ships with sensitive magnetometers on long cables.

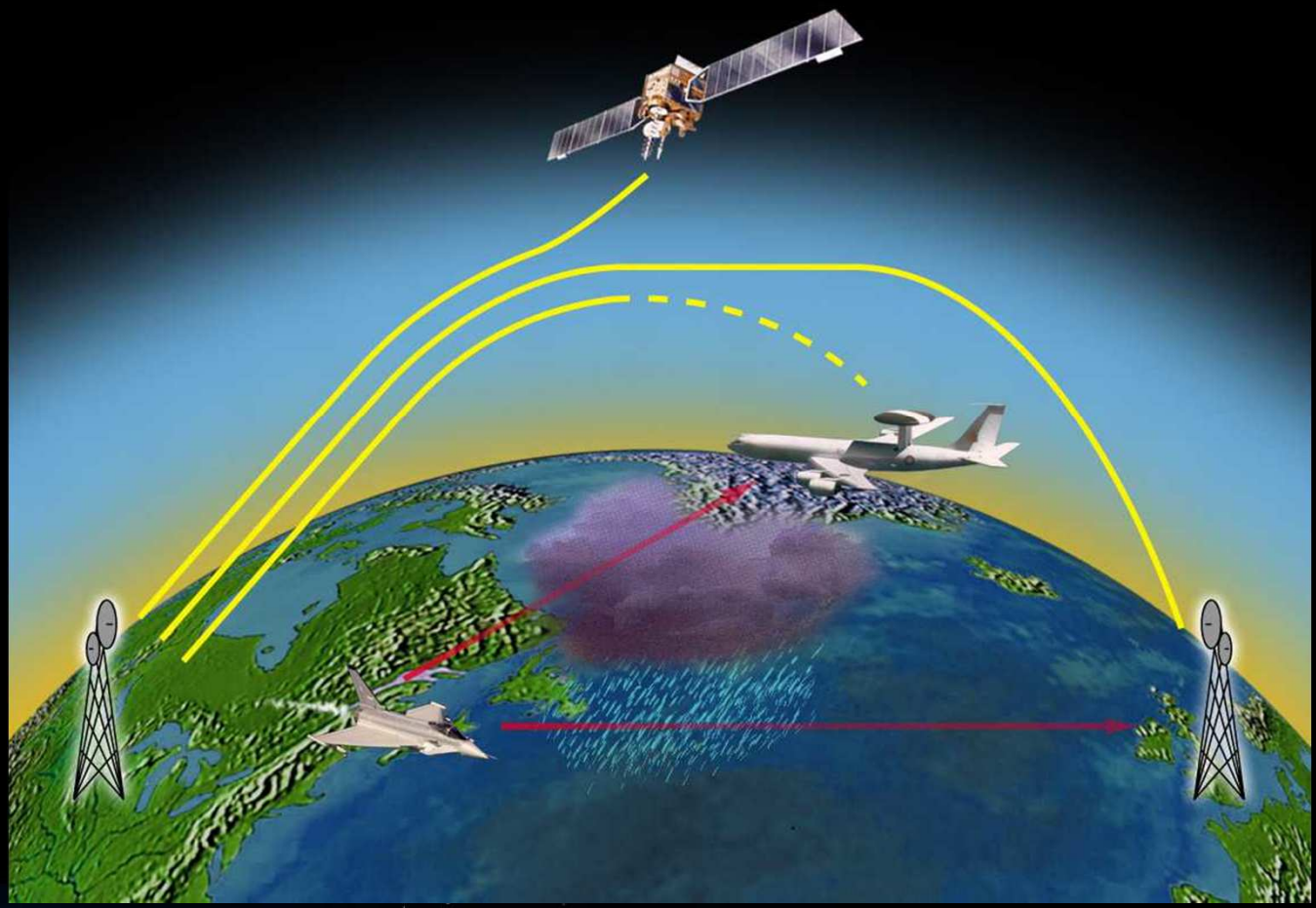
The Scandinavian Power Grid

Statnett, the Norwegian Power Grid Company, supervises and co-ordinates the operation of the entire Norwegian power system.

The have monitored GIC for about 15 years.

Their conclusion: The Norwegian grid is fairly robust - even for a super storm.

Radio communication i polar regions difficult



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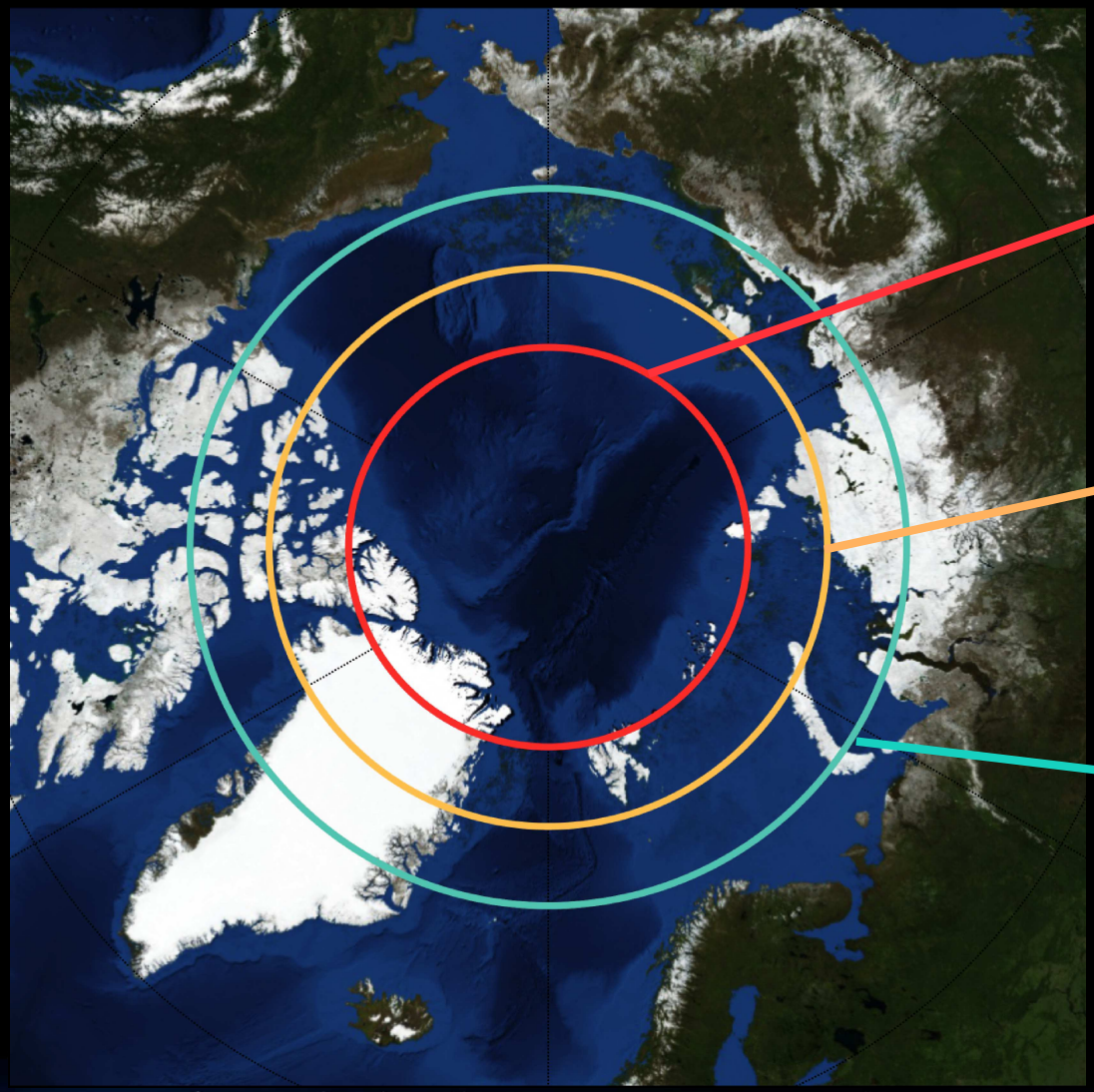
Limited Broadband and radio communication in the North



Theoretical limit (80º)

Practical limit (76º)

Problems occur (72º)

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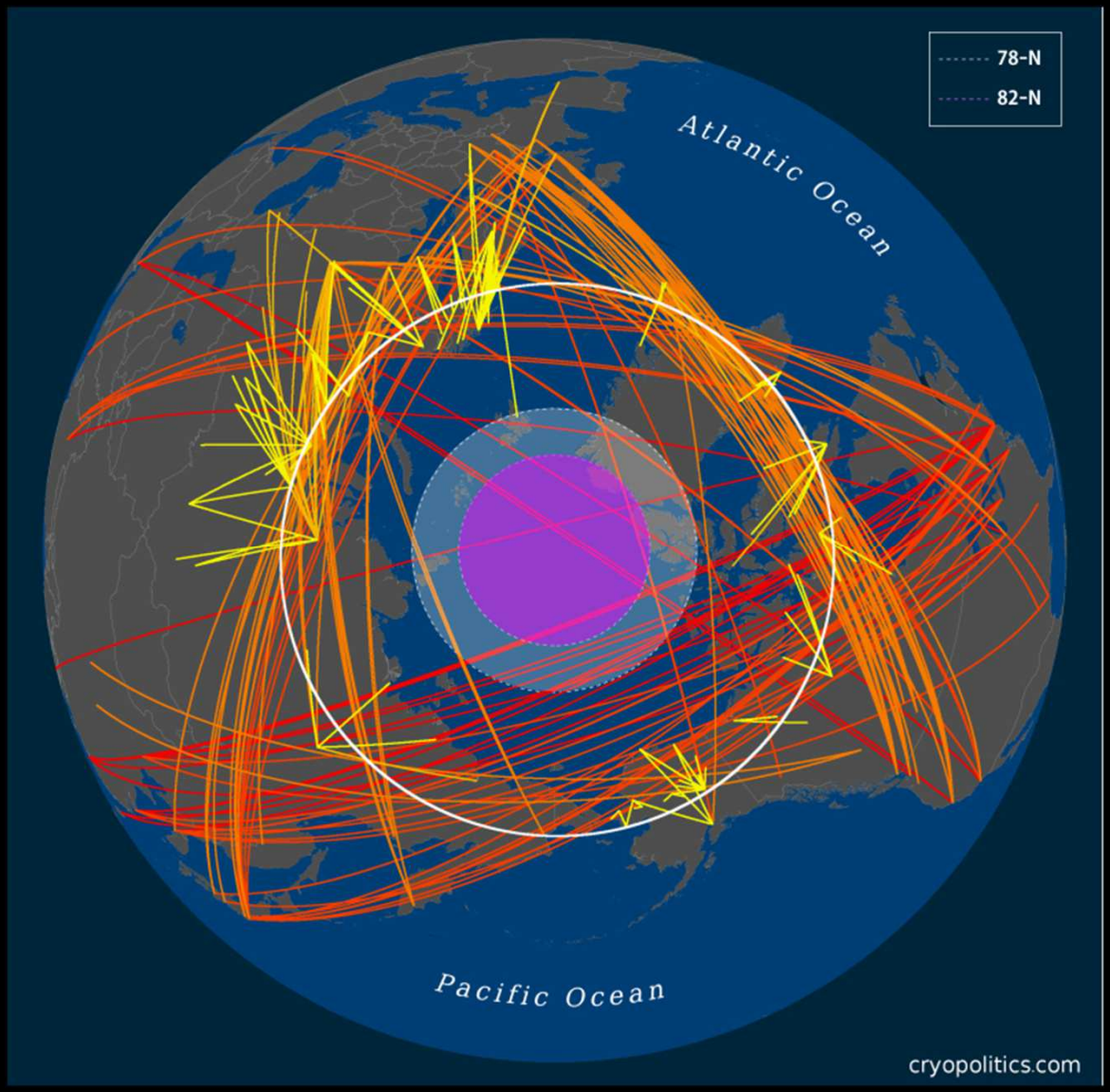
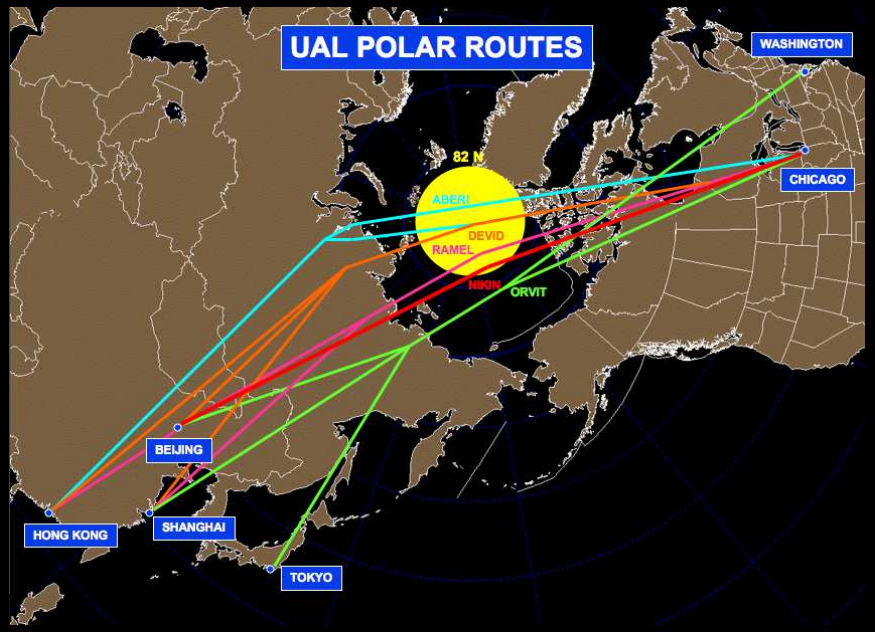
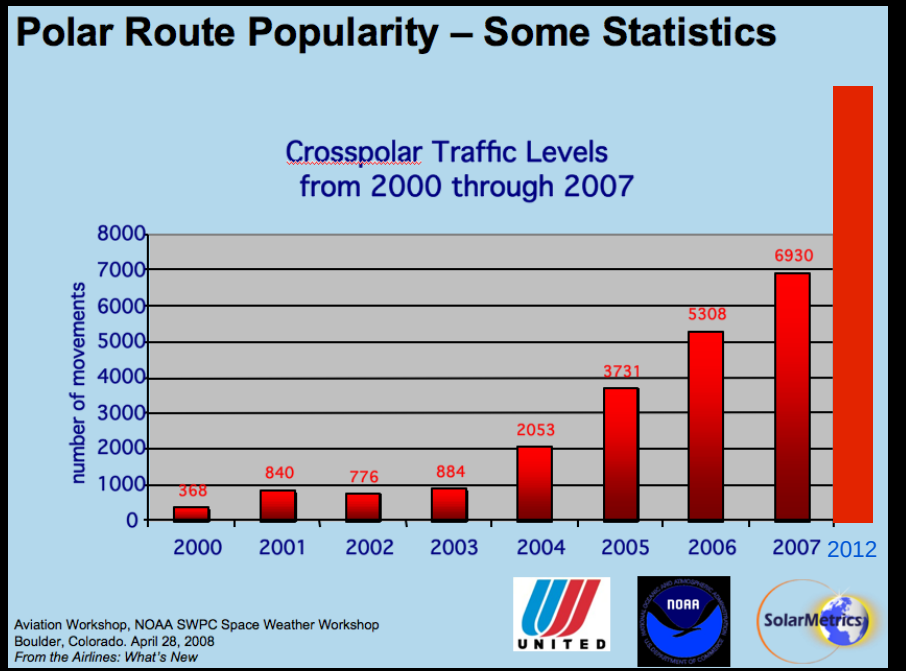
Polar routes

- Polar routes : 11.214 flights in 2012 (3,365,000 passengers)
- No satellite communication north of 82 degree







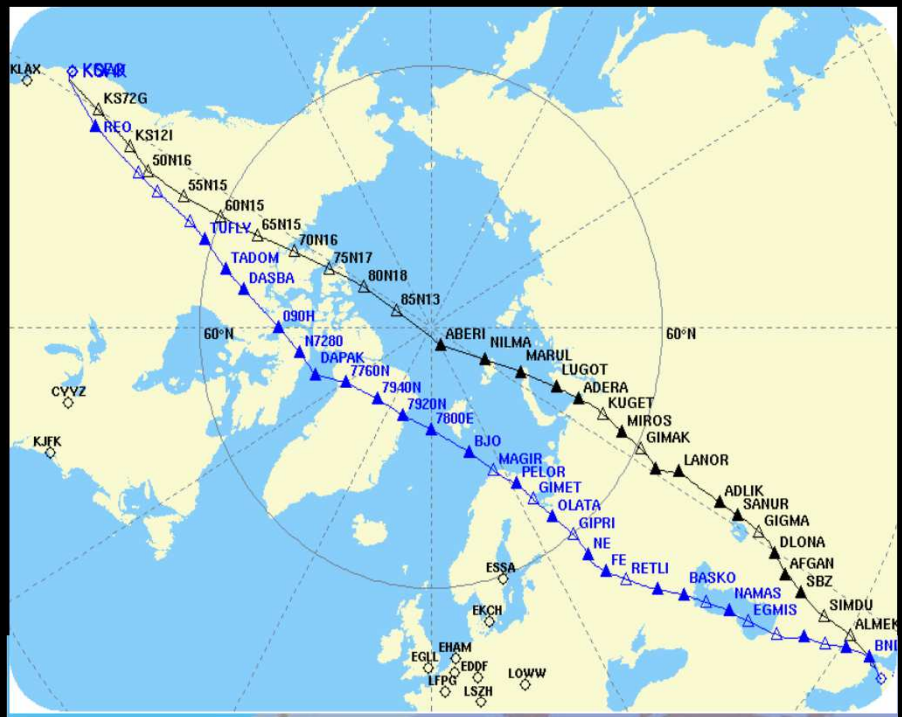
Arctic - Highway in the Sky

65 000 transits over Norwegian airspace

Increasing by >15% annually

Bodø Oceanic Control – main controll

Need high quality navigation and communication



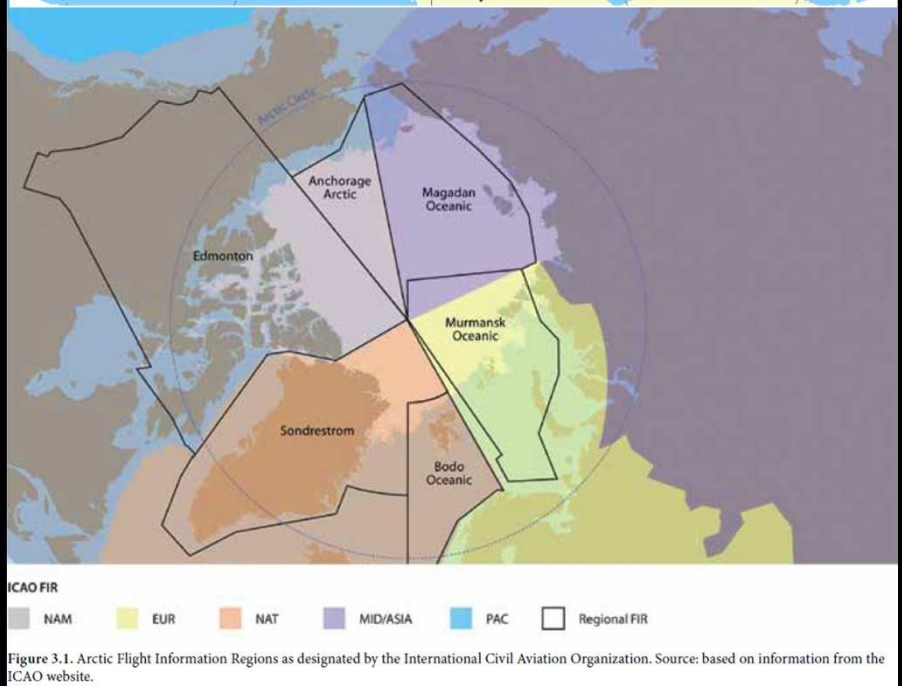


Figure 3.1. Arctic Flight Information Regions as designated by the International Civil Aviation Organization. Source: based on information from the ICAO website.

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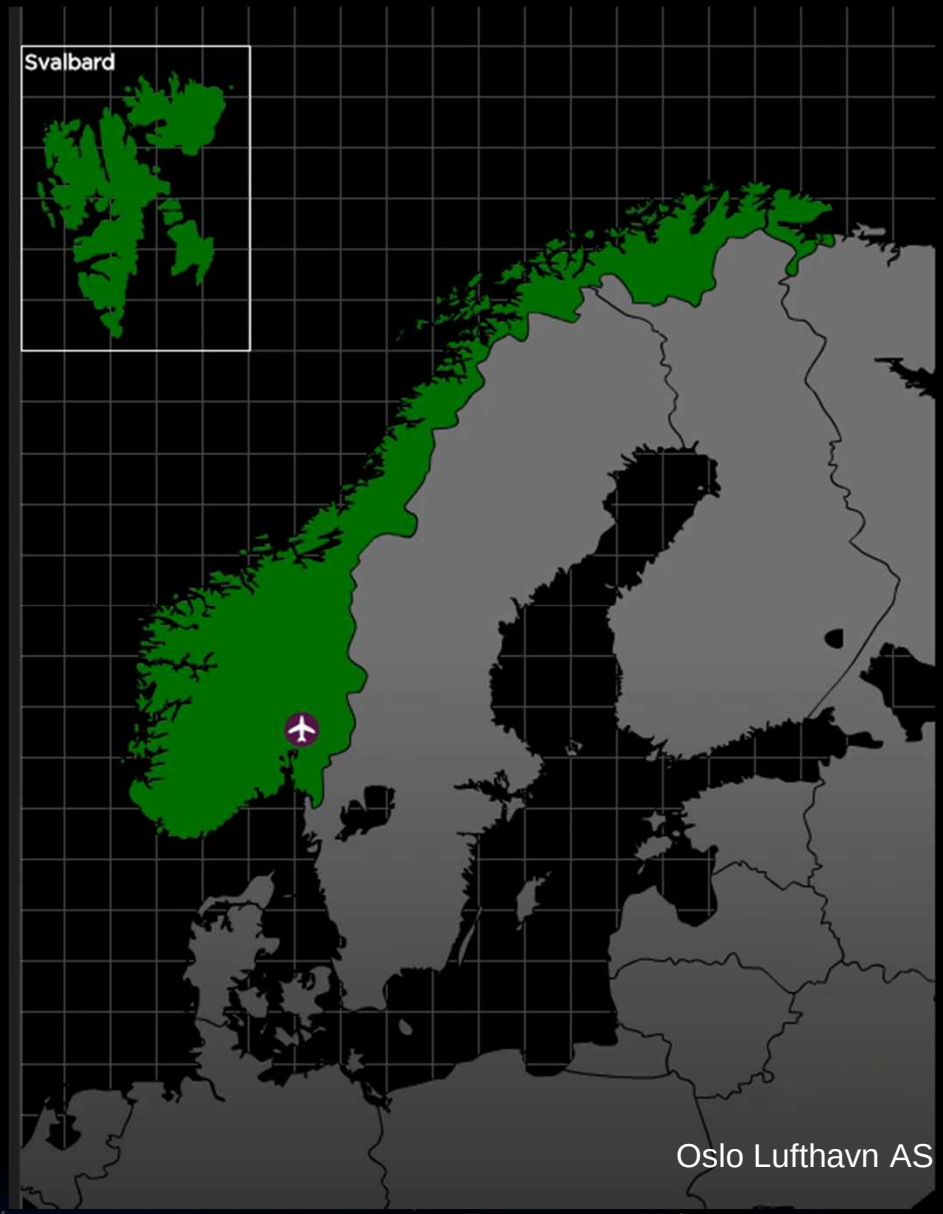
Aviation in the Arctic



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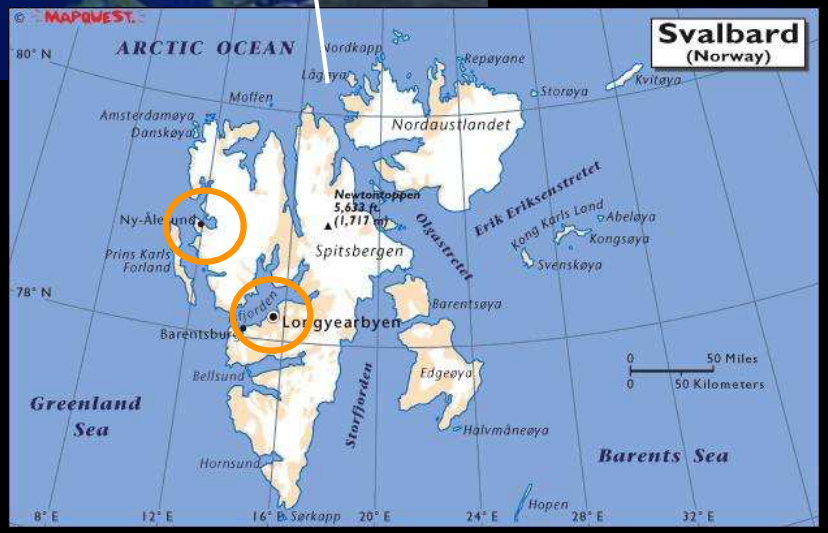
Flights to, from and at Svalbard



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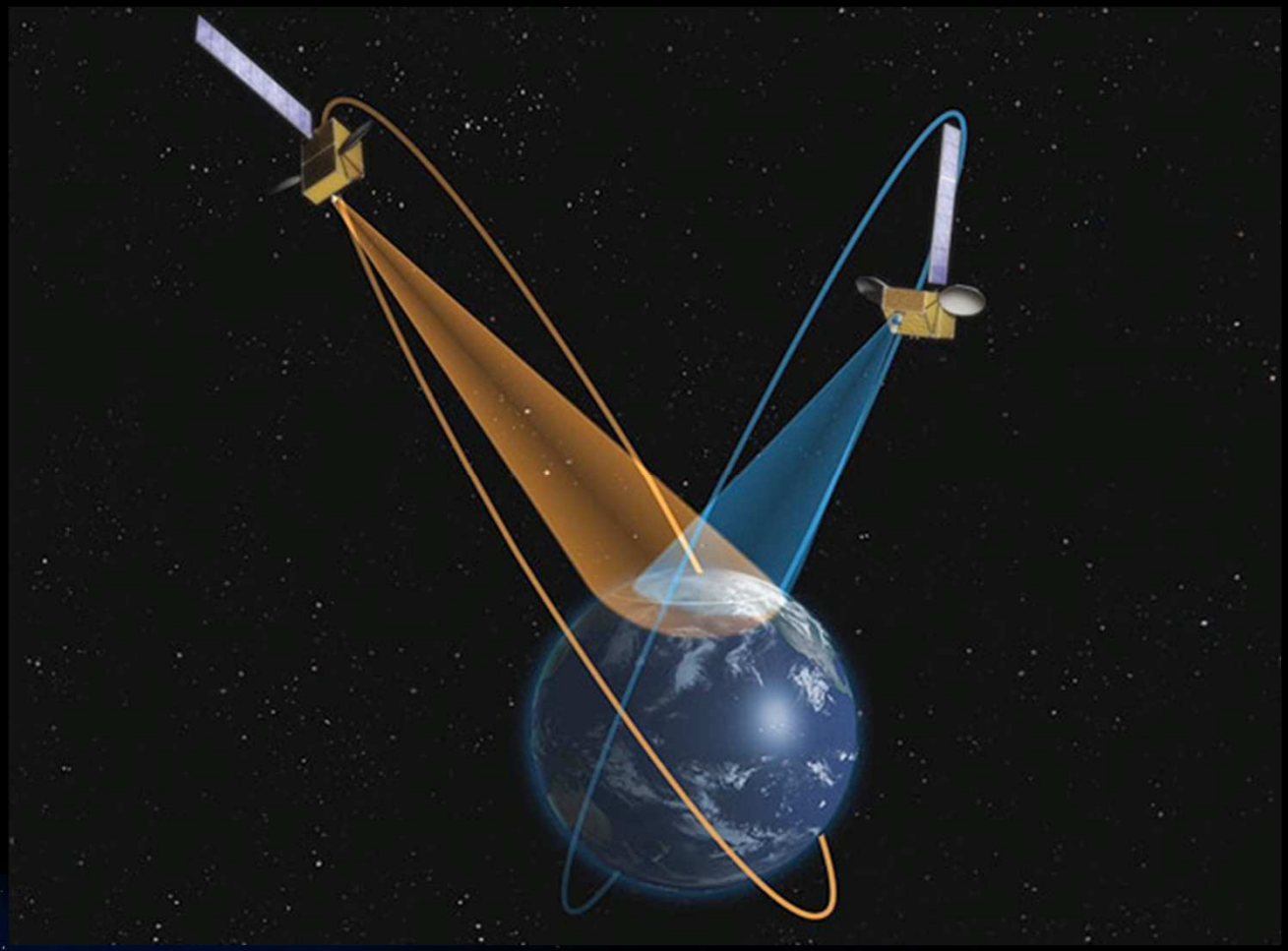
Polar Communication satellites

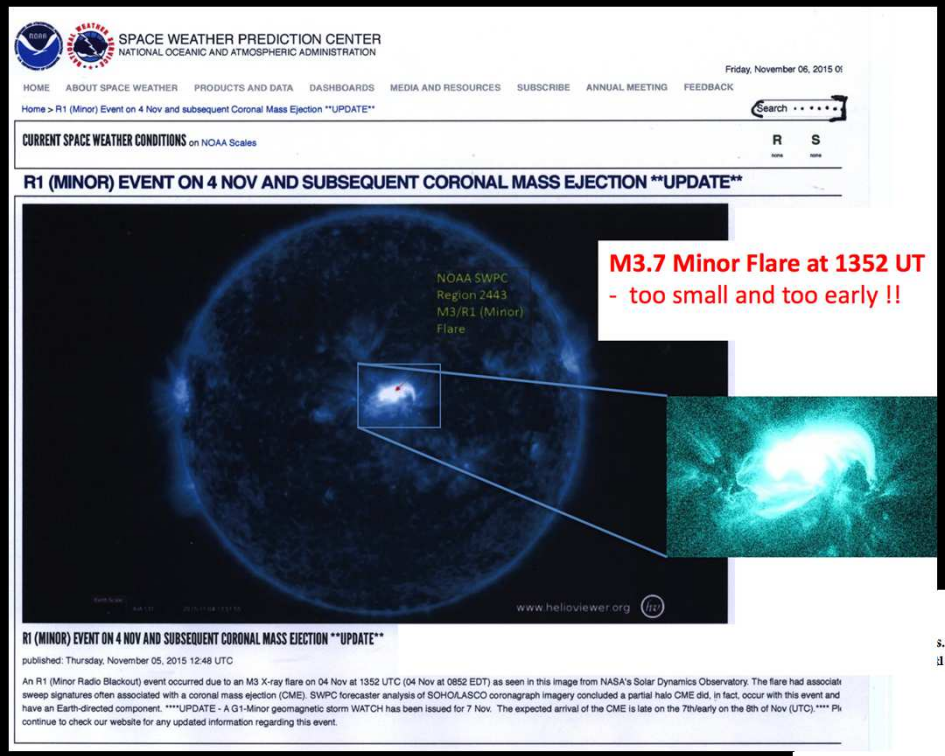
- The Norwegian Government is exploring the possibility of new communication satellites for the Arctic - possibly in collaboration with other arctic countries.

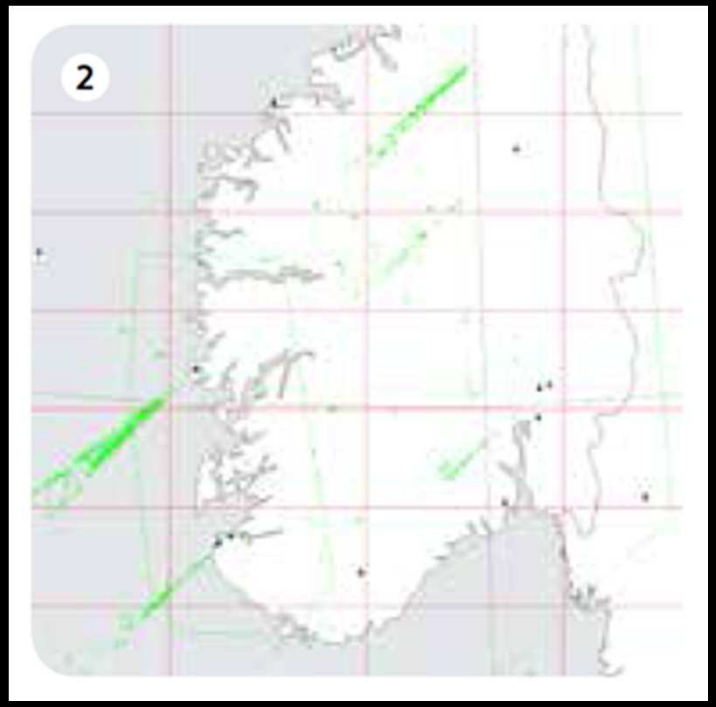


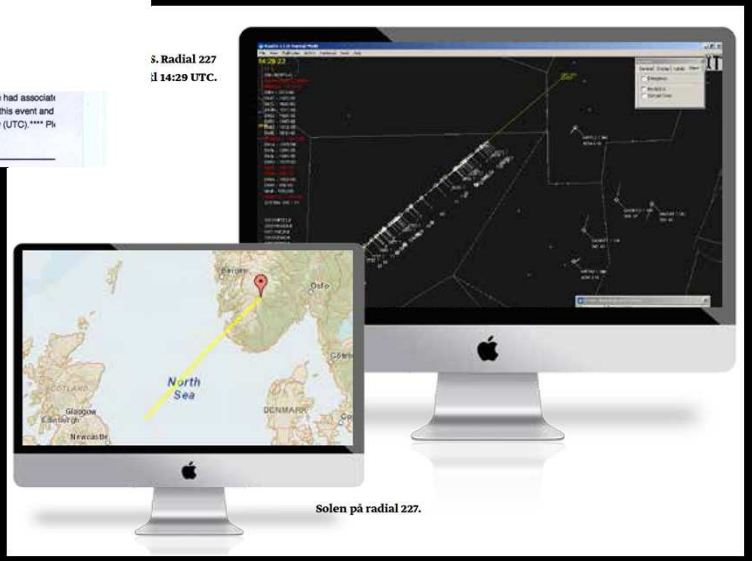
Radio burst affected flight radars

4 November 2015

The event led to 5776 delay-minutes for SAS

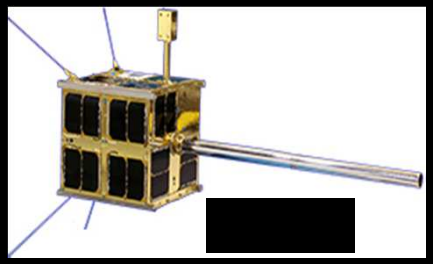




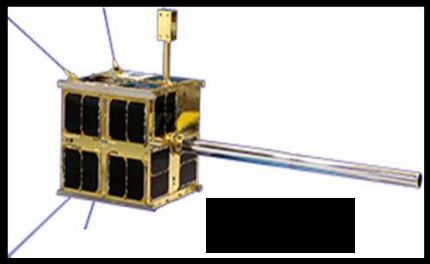


Avinor

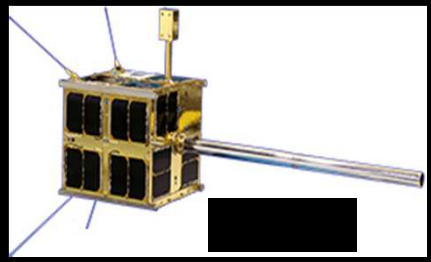
Norwegian small satellites



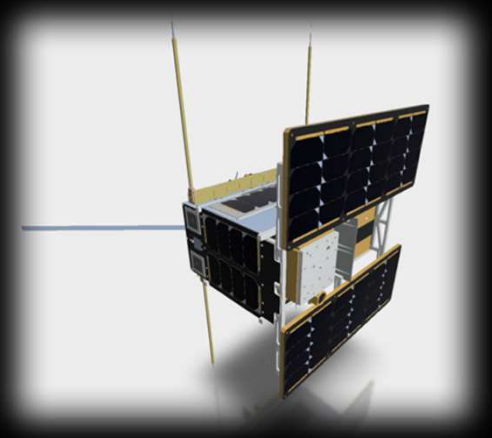
AISSat-1 (2010)
(2010)



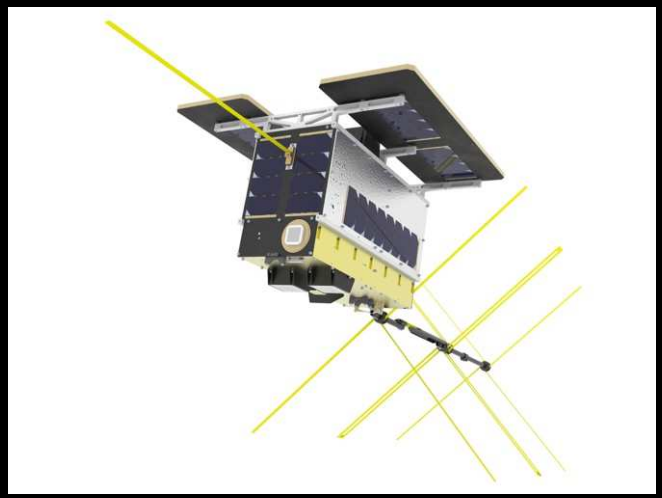
AISSat-2 (2014) (2014)



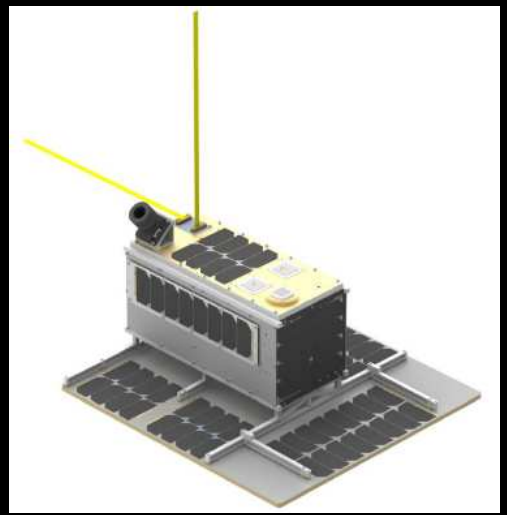
AISSat-3 (Q4 2017)



Norsat-1 (Jul. 2017)
- AIS
- Space weather
- Solar TSI



Norsat-2 (Jul. 2017)
- AIS
- VDES demonstrator



Norsat -3 (Q2 2019)
- AIS
- Navigation radar detector

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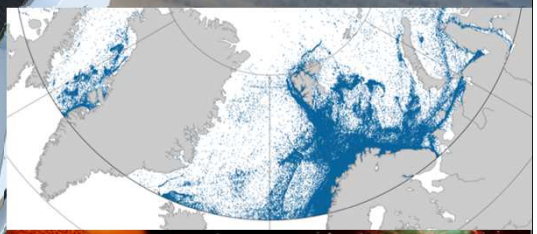
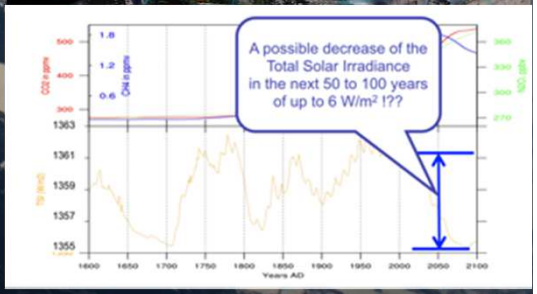
NORSAT-1

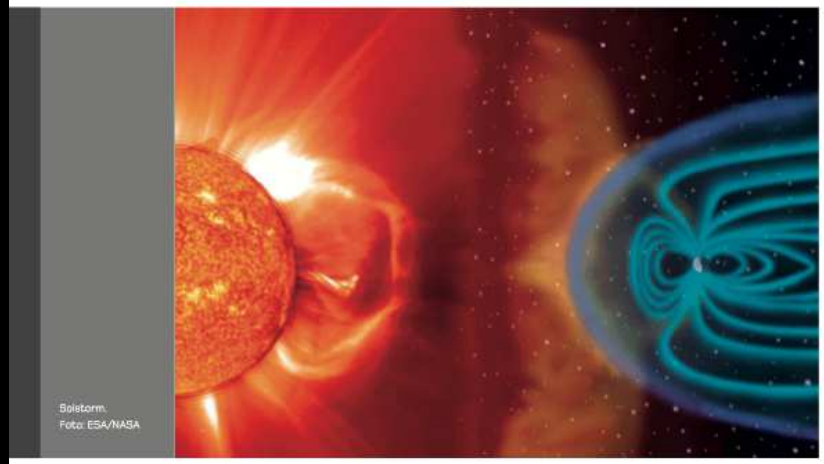
- **Primary payload :**
  - Next generation An Automatic Identification System (AIS) receiver from **Kongsberg Seatex** to acquire messages from maritime vessels;
- **Secondary payload** :
  - A Langmuir Probe instrument, intended to measure ambient space plasma characteristics
  - **University of Oslo**
- **Secondary payload :**
  - A Compact Lightweight Absolute Radiometer (CLARA), intended to observe total solar irradiation and variations over time.
  - **Physikalisch-Meteorologisches Observatorium Davos**





DSB - National Risk Analysis

The Directorate for Civil Protection and Emergency Planning (DSB)


Solstorm.
Foto: ESA/NASA

5.6 SOLSTORM

BAKGRUNN

Solens overflate består av plasma som kan betraktes som en meget varm elektrisk ledende gass. Gassen strømmer kontinuerlig ut fra solen, og sammen med elektromagnetisk stråling, påvirker dette jorda og vårt nære verdensrom ved en rekke prosesser som med en fellesbetegnelse kalles romvær. Til tider oppstår voldsomme eksplosjoner i solas atmosfære, såkalte solstormer, hvor store mengder partikler, stråling og gass med magnetfelt slynges ut i verdensrommet. Jordas magnetfelt beskytter mot solstormer, men ved polområdene er denne beskyttelsen svakere.[72] Romvær og solstorm er derfor et særlig aktuelt tema for Norge siden vi ligger langt nord.

Den såkalte *Carrington-stormen* i 1859 refereres ofte til som den kraftigste solstormen man har hatt erfaring med. Telegrafsystemet ble kraftig rammet, operatørene fikk elektriske sjokk, og branner oppsto i telegrafbygninger som følge av solstormen. Også i 1921 opplevde man en stor solstorm. Denne solstormen var ikke så kraftig som den i 1859, men medførte samme type konsekvenser og utfordringer for datidens samfunn.

Flere kraftige solstormer har de siste 20 til 50 årene medført forstyrrelser og avbrudd i tele- og strømforsyning med ujevne mellomrom og ulik varighet. I 2003 var det mange kraftige elektromagnetiske stormer på sola. I forbindelse med de såkalte *Halloween-stormene* ble det meldt om tekniske problemer med satellitter og satellittelefoner fra flere deler av verden. På grunn av problemer med radiokommunikasjon ble internasjonal luftfart på transatlantiske og polare ruter midlertidig reduserte og trafikken omdirigert, og det ble sendt ut advarsel om økt strålefare for flypassasjerer. I USA ble også enkelte store krafttransformatorer skadet og ødelagt, og store områder ble mørklagt i noen timer. Kostnader som følge av solstormen ble anslått til å være minst fire milliarder dollar.

Også i Sverige mistet mange tusen mennesker strømmen i en kort periode som følge av denne solstormen.[73]

72 NATO/EAPC, working paper 30 August 2011; Norsk Romsenter (NRS); www.krisinfo.no (14.12.2011).

73 National Research Council of the National Academies (2008): *Severe Space Weather Events–Understanding Societal and Economic Impacts*, Workshop Report; U.S. Department of Homeland Security, Federal Emergency Management Agency (FEMA), National oceanic and atmospheric administration (NOAA), US Department of Commerce, Swedish Civil Contingencies Agency (MSB) (2010): *Managing Critical Disasters in the Transatlantic Domain – The Case of a Geomagnetic Storm*. Workshop Summary, February 23.-24.2010.

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Northern Lights - Tourism

Hurtigruten

Users of Space Weather in Norway

Who:	Why:
• Oil&Gas companies	Navigation, positioning and exploration activities
• Aviation	GNSS navigation and HF communication (S&R, Avinor etc.)
• Maritime Sector	GNSS navigation and HF communication
• Power grid operators	Ground Induced Currents and GPS timing (NVE/Statnett)
• Satellite operators	Damages to systems (Statsat/Telenor)
• Survey, Construction, etc.	GNSS positioning
• Tourism sector	Aurora forecasts

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Summary

Several Norwegian agencies and companies are aware of their needs within space weather and ask about national services.

With the expected increased oil and gas activities in the Barents Sea, more traffic through the North West passage, more GNSS-users on land and ocean as well GNSS-usage in aviation the demands for reliable space weather services will also increase.

However, until now very little coordination towards an operative national system

Today Norway also have its own small satellites that are affected my space weather and space debris. As well as satellites with space weather instrumentation.

Our goal is to be in the front on Arctic Space Weather part of the European development.

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