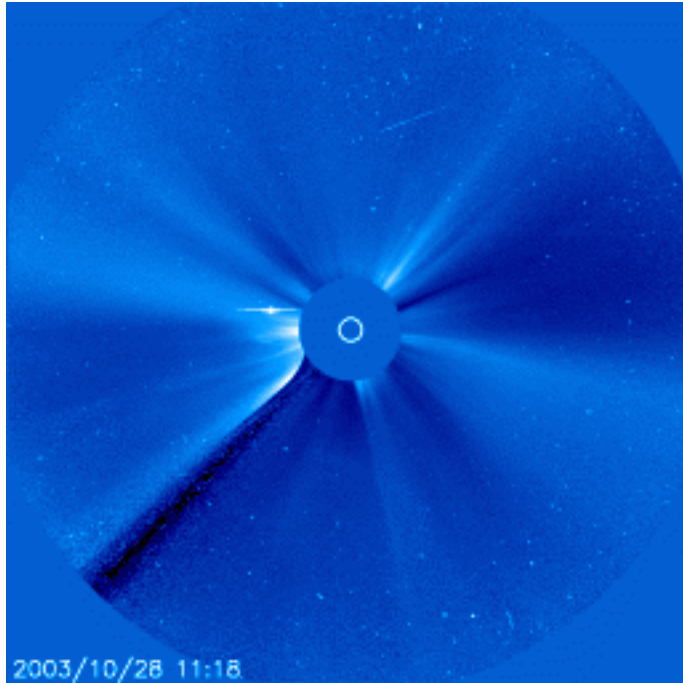


# Magnetometers and Riometers

Farideh Honary





**'Space Weather'** has severe effects on communications amongst other things.

## **Studies are of importance to:**

airlines, maritime agencies, military, broadcasters, insurance companies, climate change scientists, satellite operators, human space flight agency

# Ground-based Facilities



**CUTLASS**



IRIS phased array riometer system at Kilpisjärvi, northern Finland

**IRIS**



**DASI**

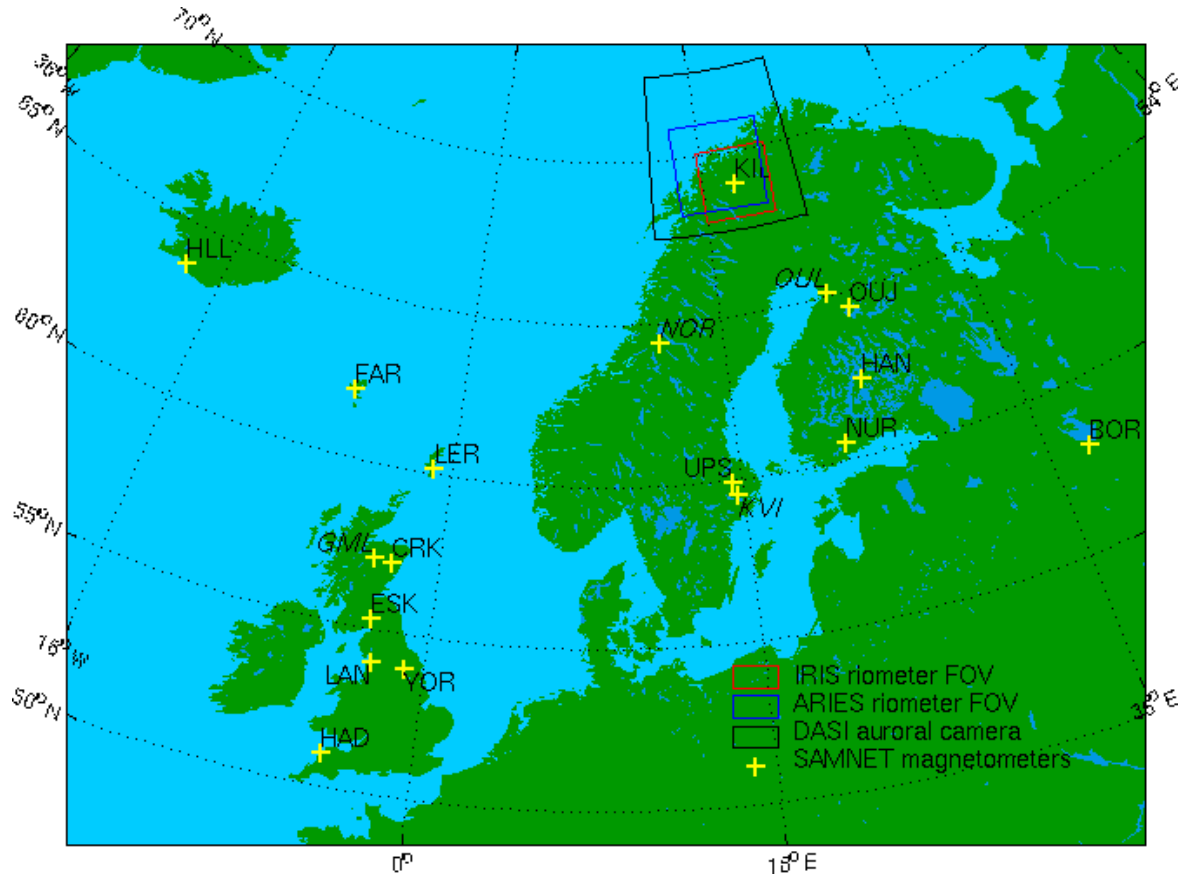


**Magnetometer**



**EISCAT**

# Instrumentation operated by Lancaster



**Riometers (e.g. IRIS)** measure directly the amount of HF absorption

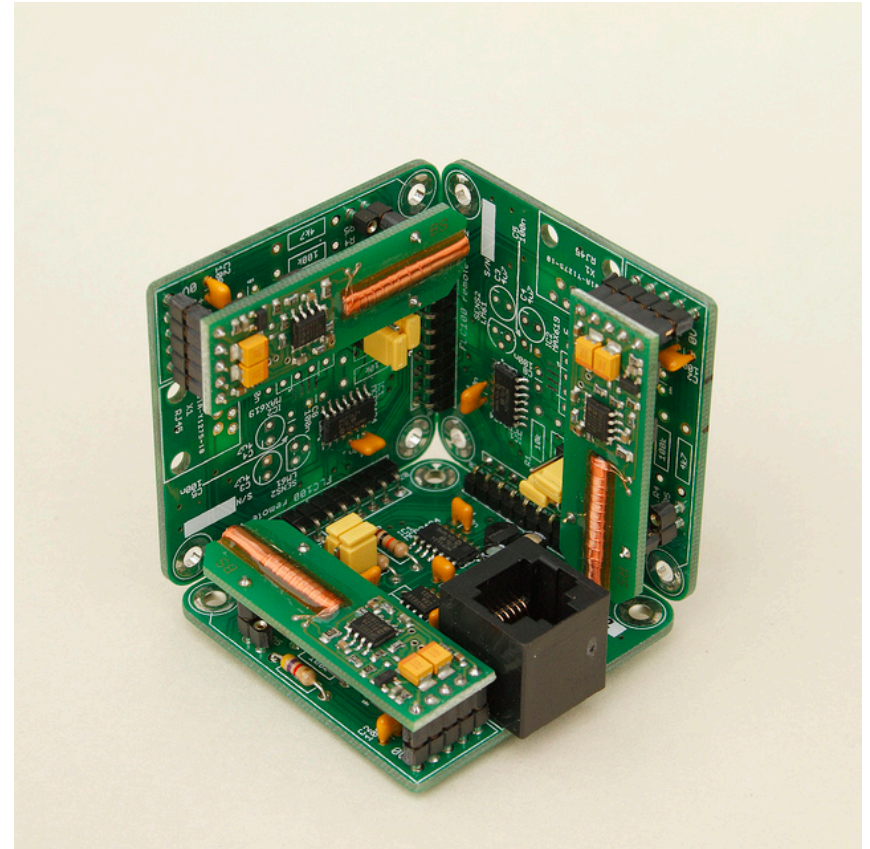
**Magnetometers (e.g. SAMNET)** detect changes in the magnetic field caused by electrical currents flowing in the ionosphere

# Citizen-science magnetometer network

- operated by schools and individuals.
- Full-field measurements, low-power, wireless magnetometers for auroral detection and citizen science.
- 30s,  $\sim 10\text{nT}$  resolution; normally single-axis measurements but three-axis versions possible.
- Data transfer uses rsync or rsync-like HTTP method.
- Real time transfer with sub-second delay using signed UDP packets (optionally to multiple hosts).

# A power-over-ethernet (PoE) version

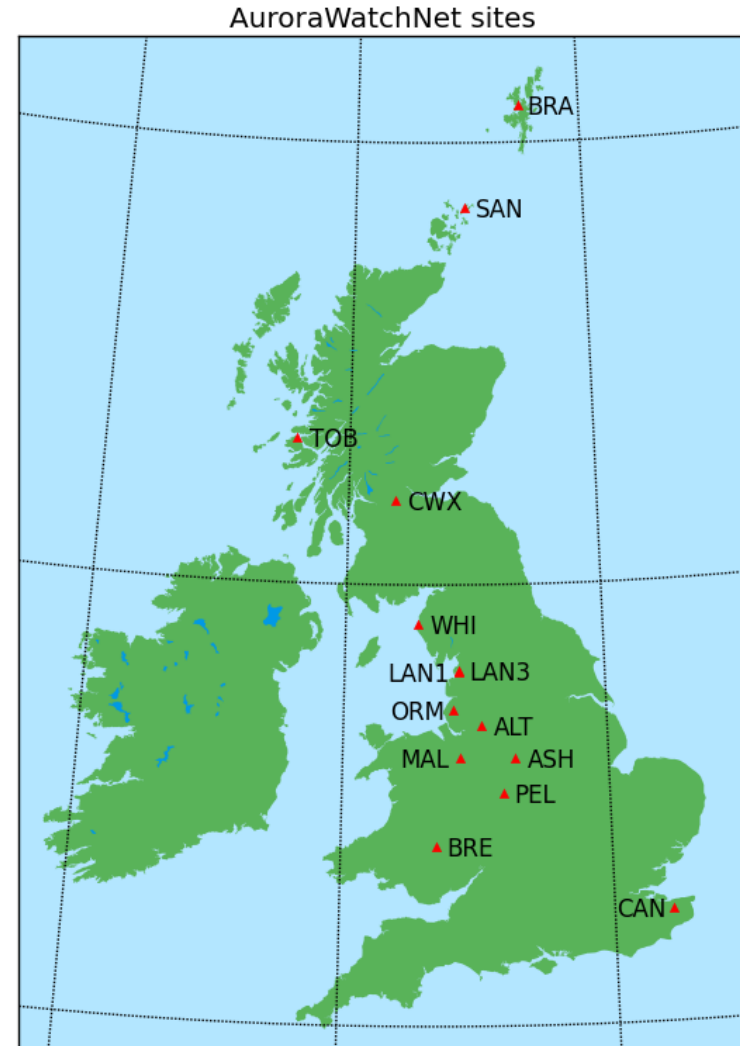
- *much* better performance, 5s,  $\sim 0.1\text{nT}$  resolution and better stability.



AuroraWatchNet 3-axis sensor unit.

# AuroraWatchNet sites

- Two sites at Lancaster.
- Ormskirk operated by Met Office as a trial.
- CWX operated by Cumbernauld Weather.
- 10 sites to be operated by schools.
- All sites will transfer data to Lancaster every ~ 3 minutes.
- Data is available under Creative Commons Non-Commercial Share-Alike 4.0 licence, public access has 2 day embargo.



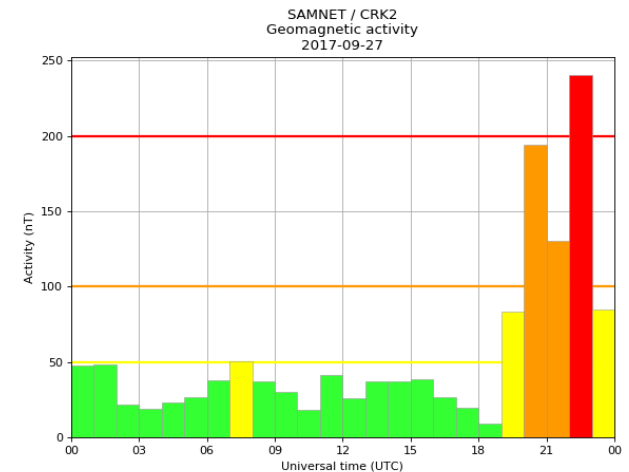
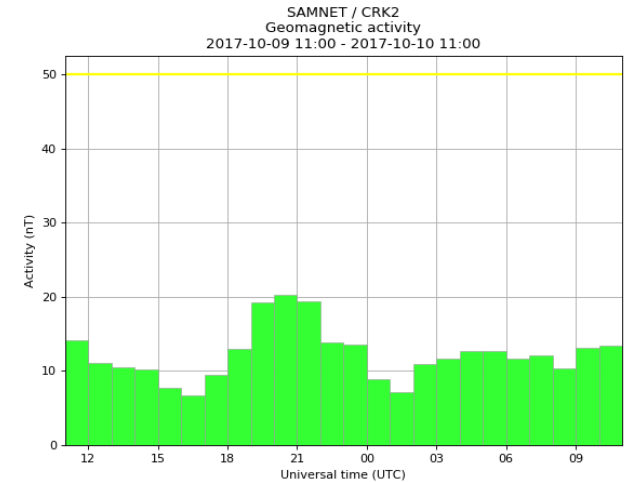


# Aurora Watch UK

<http://aurorawatch.lancs.ac.uk/>



Over 300,000 followers





# Aurora



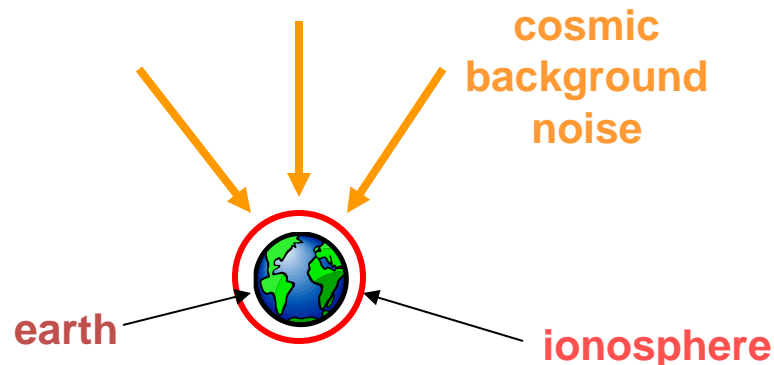
## Impact of AuroraWatch:

RAS survey in 2011 has reported a range of positive impacts including. The survey attracted 9971 responses:

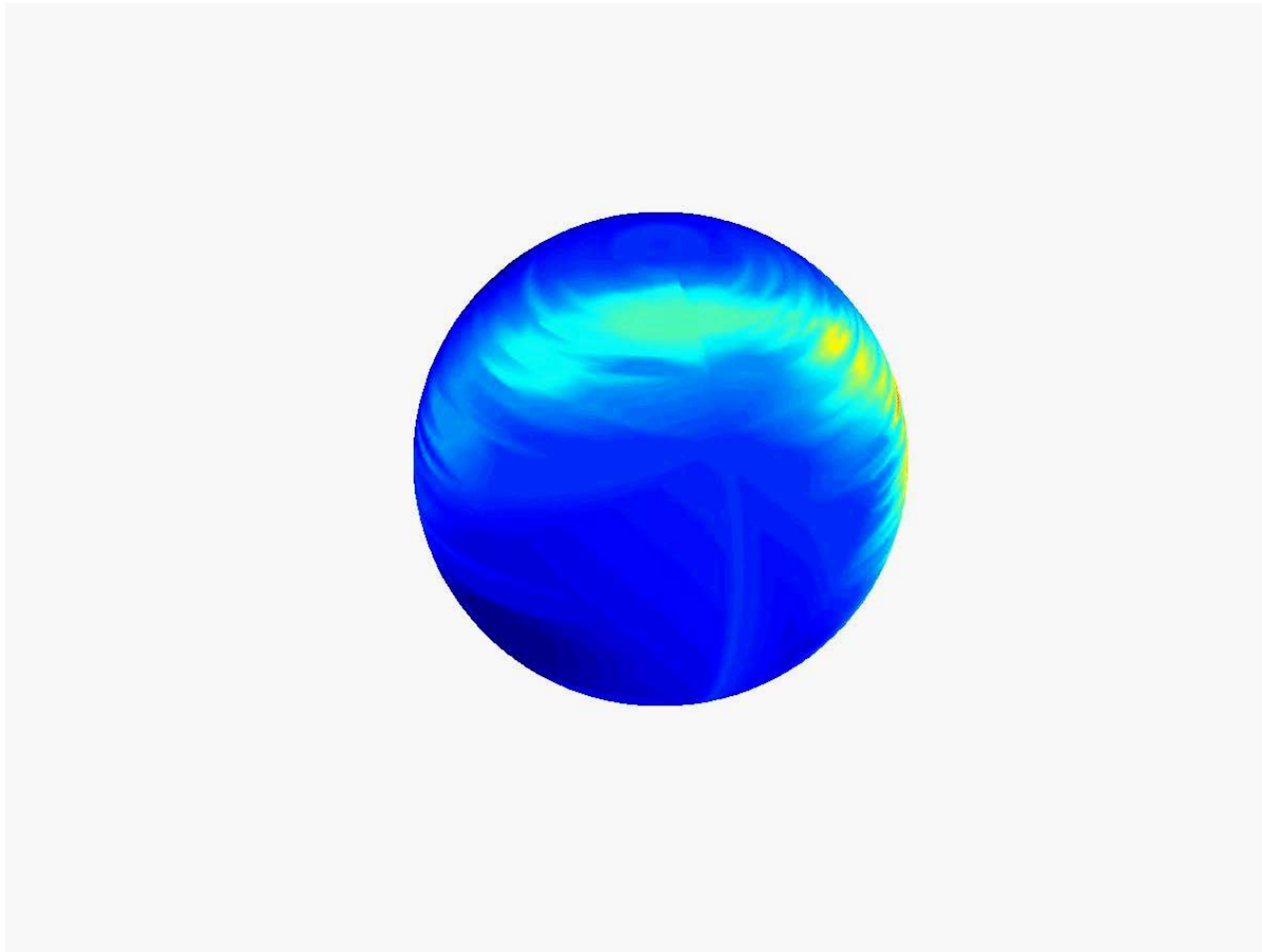
1. watch more science on TV (3667)
2. Read more science magazine (1348)
3. Read more science websites and blogs(3089)
4. Plan to study science (524)
5. Participate in citizen science project (865)
6. increase interest in astronomy, buying a telescope, booking a cruise to the arctic to see aurora (1400)

# Riometer

- Relative Ionospheric Opacity Meter
- Measures *cosmic radio noise power* after signals from galactic sources have passed through ionosphere.
- Ionization causes cosmic radio waves to be absorbed more strongly. Riometer records an *auroral absorption event*
- Riometer is important because it provides information on the lowest regions of the ionosphere which cannot be provided by other techniques Operating frequency usually 30–40 MHz, IRIS: 38.2 MHz (protected band)



# Cosmic Noise Power @ 38.2MHz



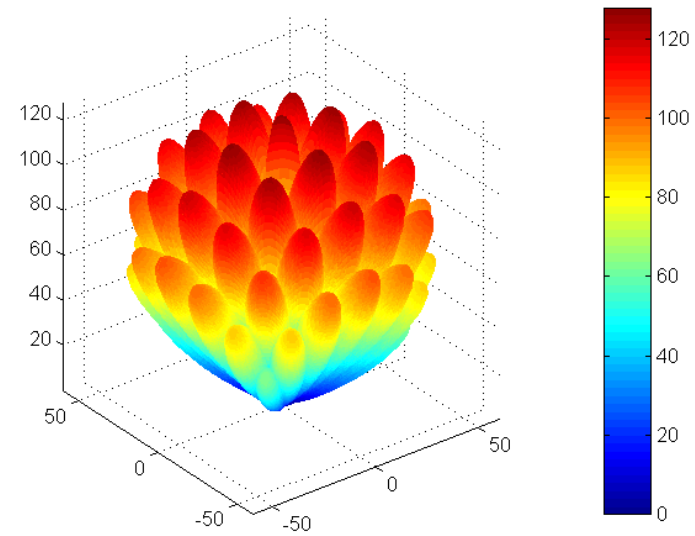
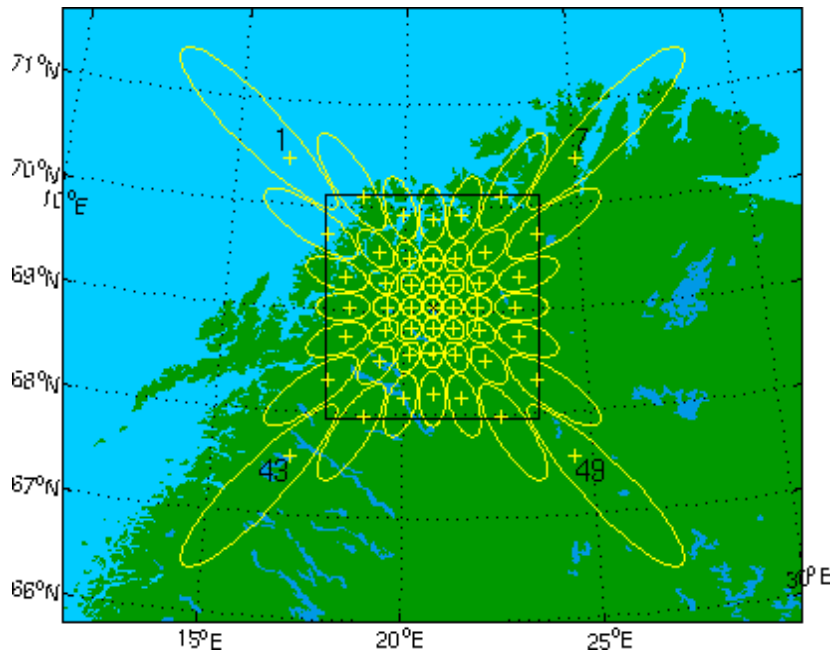
# Imaging Riometer

Imaging Riometers provide good spatial resolution and the capability of Simultaneous observation in different direction.

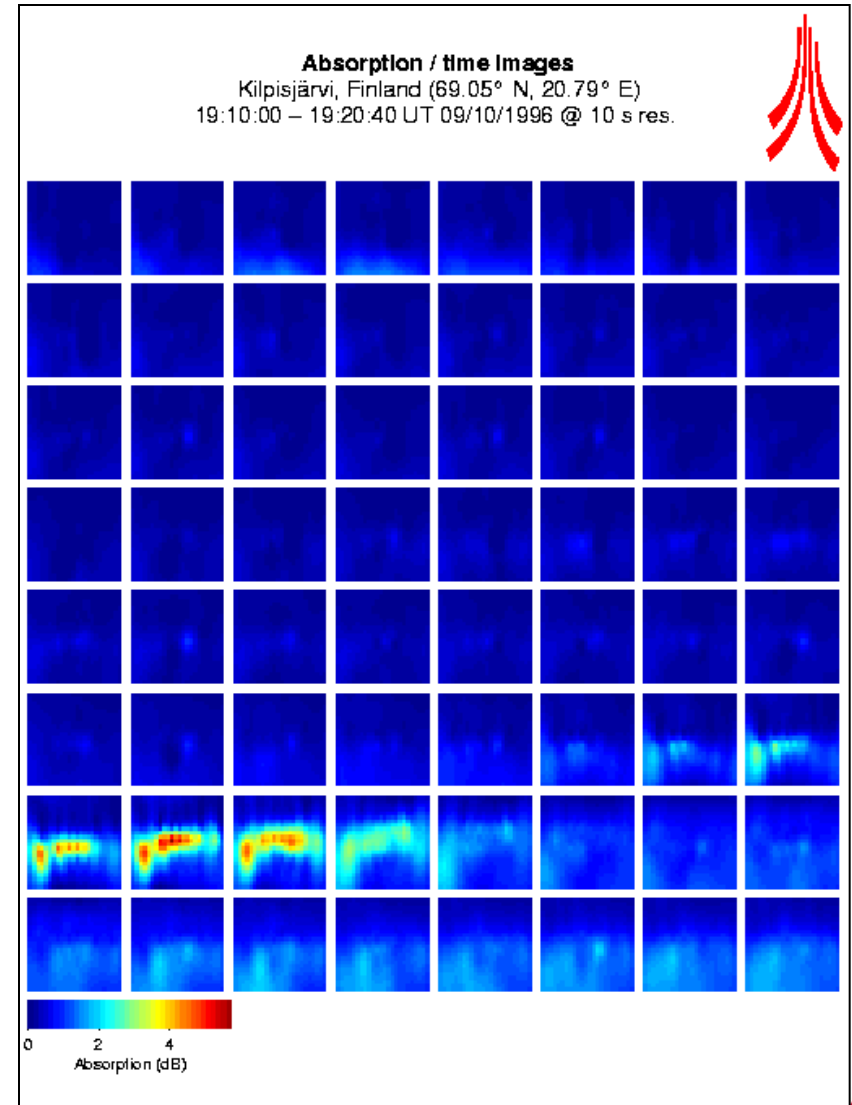
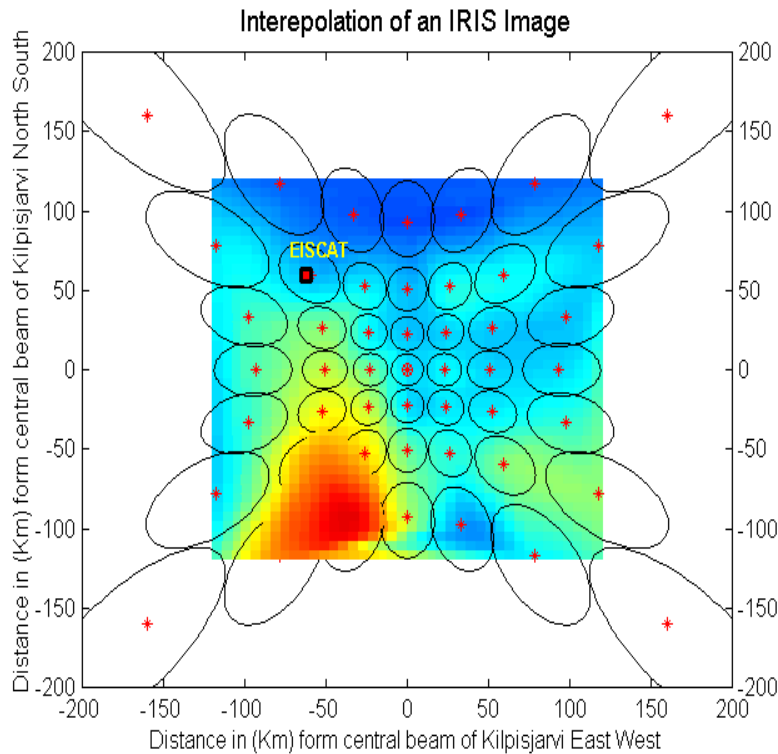
It also permits tracing the absorption Patches and understand their dynamics.



IRIS phased array riometer system at Kilpisjärvi, northern Finland



# IRIS Absorption Image generation



# Riometer Science

- Understand the mesospheric chemistry changes due to energetic particle precipitation and X-ray flares.
- Determine energy deposition into the mesosphere via energetic particles and their modulation by ULF waves.
- Investigate the role of energetic particle precipitation on the global atmospheric electrical circuit.
- Investigate the role of energetic solar particles in stratospheric/mesospheric ozone destruction.
- Producing large scale maps of absorption including Inter-hemispheric and day/night side examination of precipitation.
- Impact of auroral and solar effects on communication systems
-

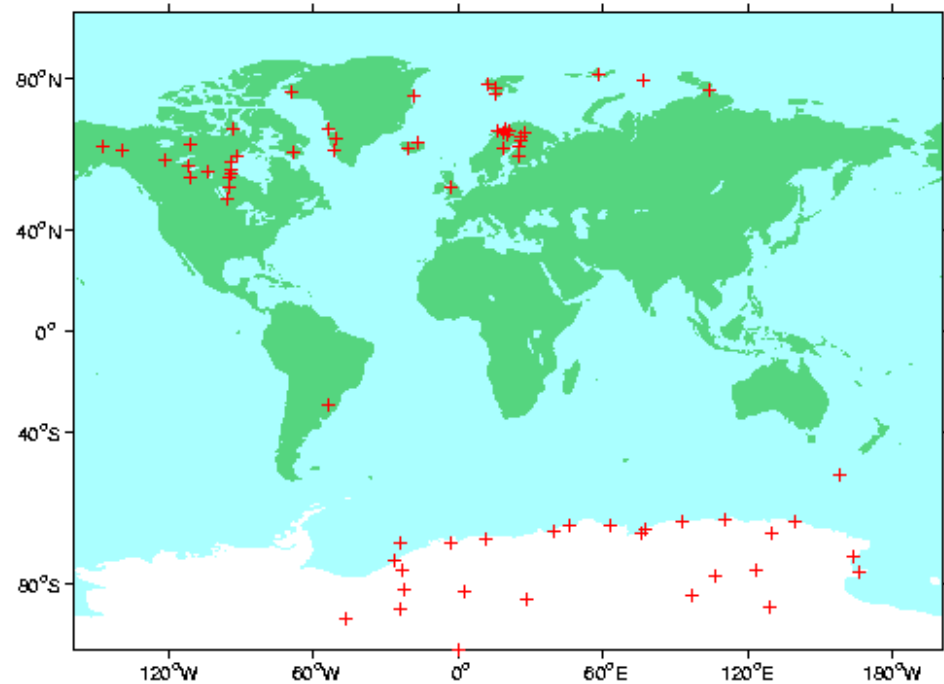
# GloRiA

## *The Global Riometer Array*



*The objective of GloRiA is to combine riometer data sets from around the world creating a virtual array which can produce “images” of high-energy electron precipitation on a global scale.*

*GloRiA incorporates riometer data from programs in the UK, Finland, Canada, US, Germany, Denmark, Japan, Russia, Australia, South Africa, Italy, Norway and China.*

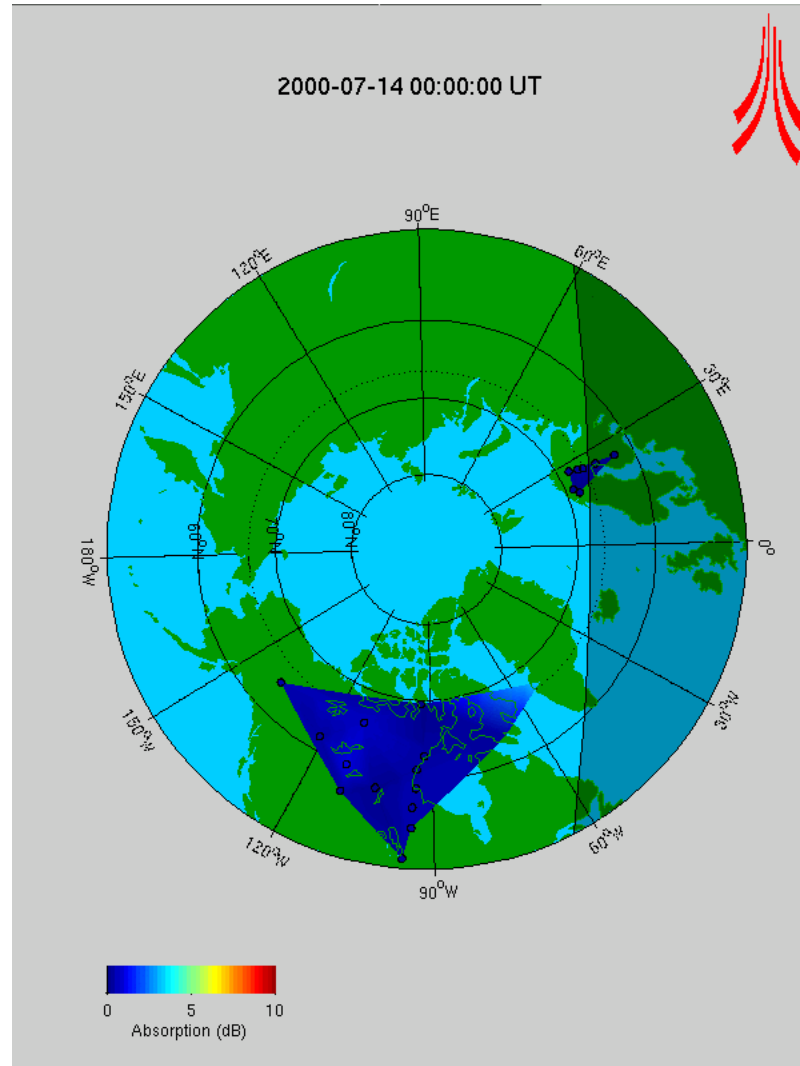




# PCA Event

Data courtesy of:

- CANOPUS
- Sodankylä Geophysical Observatory
- University of Maryland
- Lancaster University

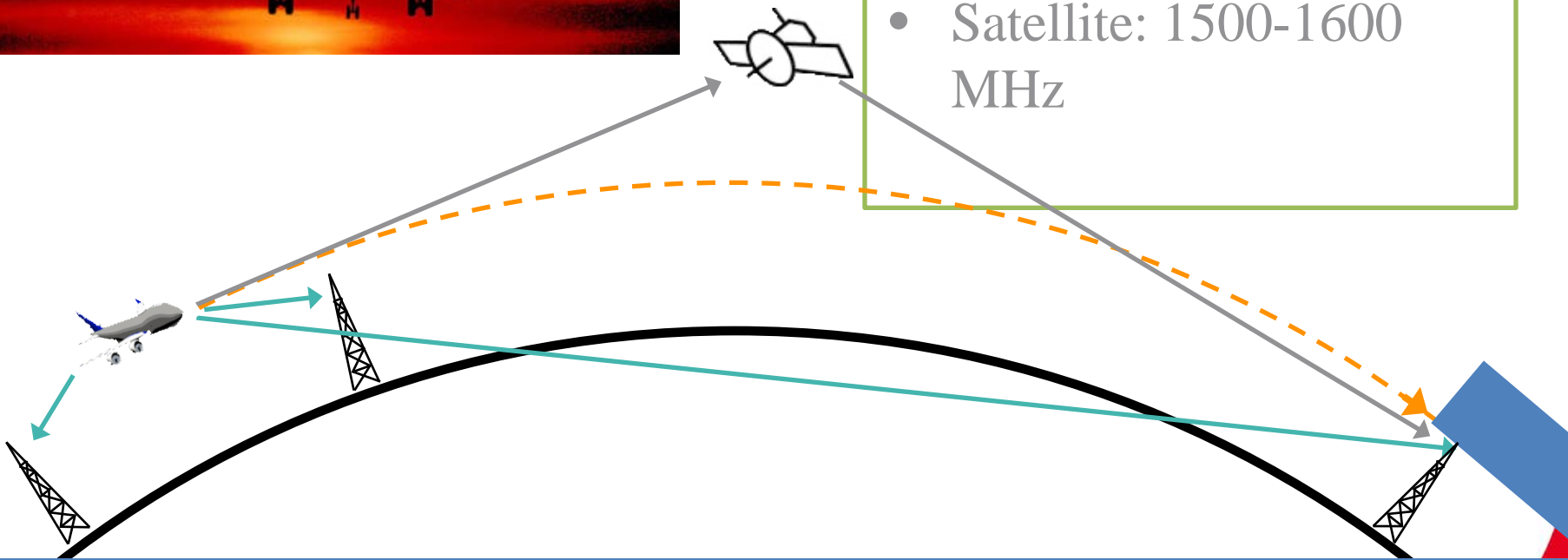


# Impact on Airline Communications



## Air-ground radio

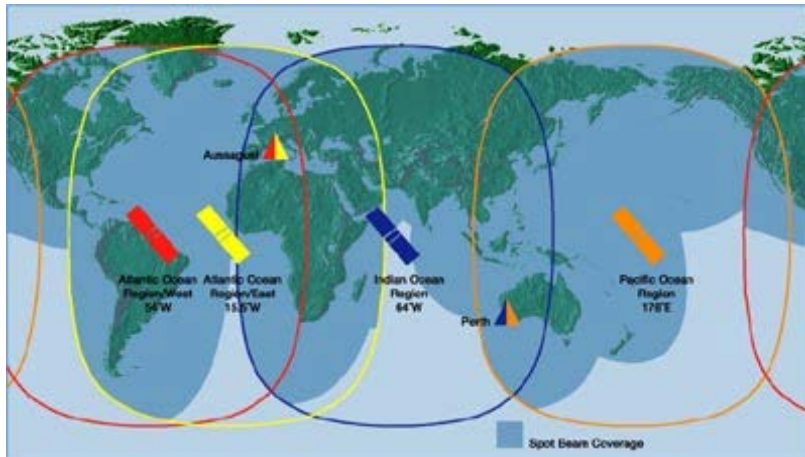
- VHF: 108-136 MHz
- **HF: 3-15 MHz**
- Satellite: 1500-1600 MHz



# Impact on Airline Communications

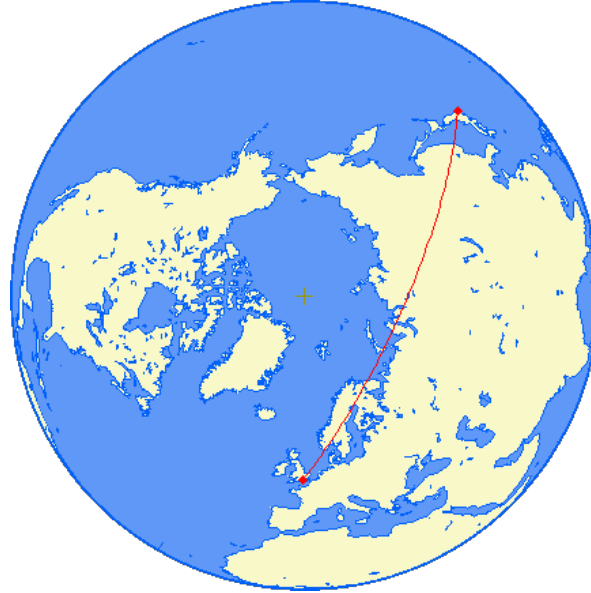


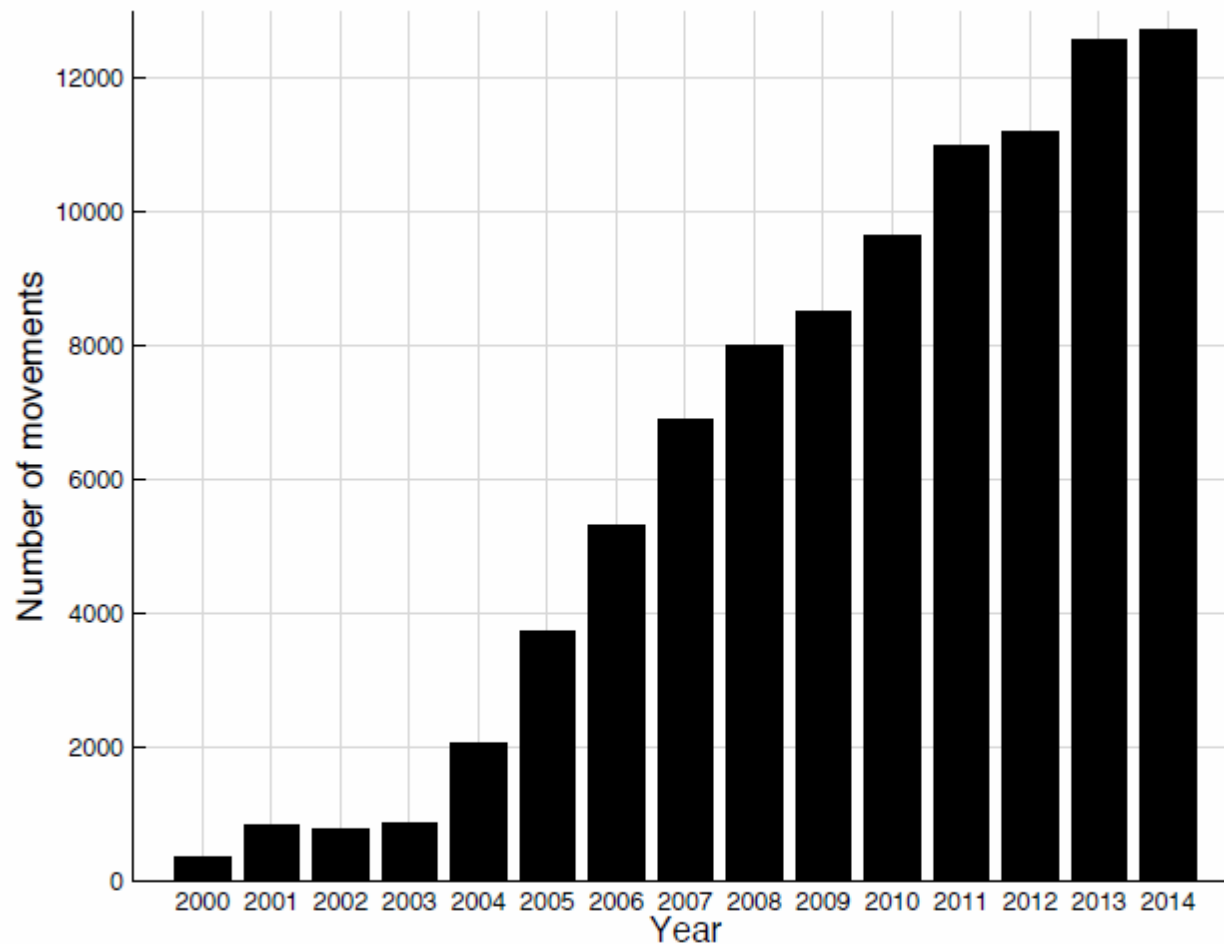
VHF coverage relatively limited



Poor satellite coverage near the poles

# Impact on Airline Communications





*Figure 2.1. Cross-polar traffic levels for 2000–2014 (2014 estimated based on the number of flights up to November) (State ATM Corporation of Russia)*

# Impact of the October 2003 “Halloween storm”

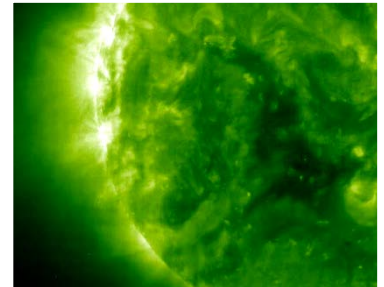
A major airline rerouted six polar flights to non-polar routes requiring fuel stops in Japan and/or Anchorage

Numerous other US flights rerouted or restricted

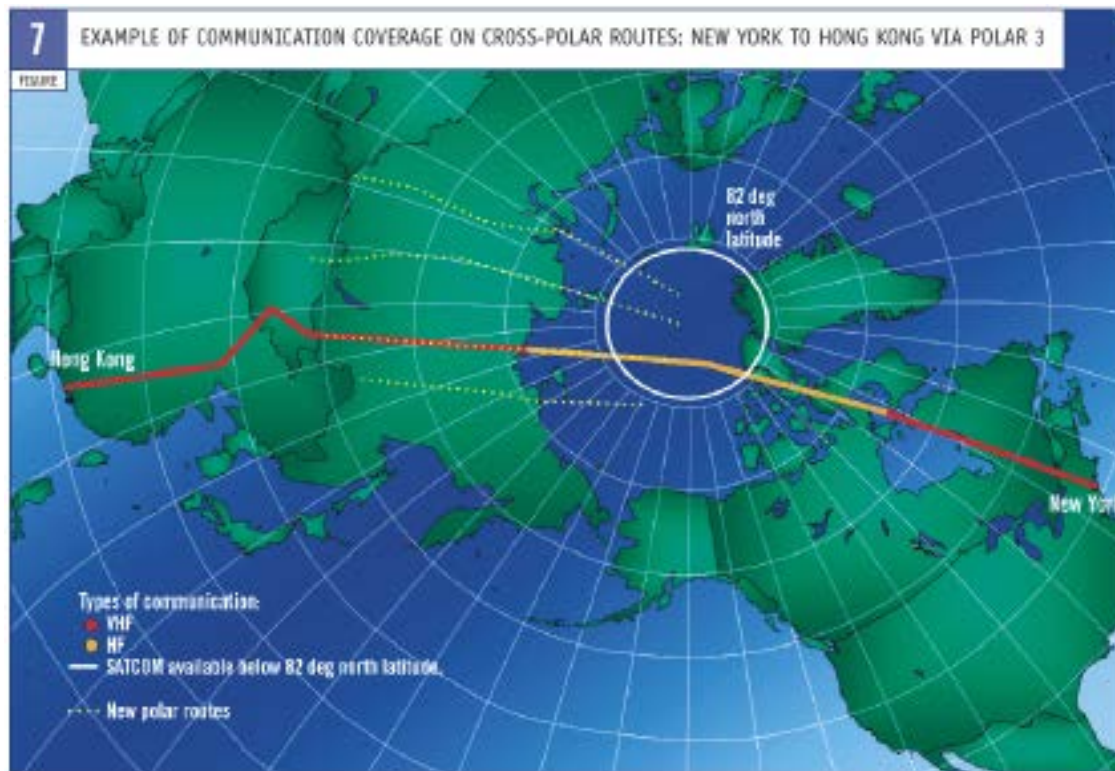
British controllers kept trans-Atlantic jets on more southerly routes than usual to avoid the communication problems

British Airways pilots deviated from the airline's flight plans and flew at lower altitudes amid concerns over health risks to passengers and crew from radiation

*Sunday Times, 9 November 2003*



# HARP - High-latitude Aeronautical Radio Prediction Service



A night sky featuring a vibrant green aurora borealis. The aurora is a vertical band of light, with a brighter, more intense section in the center. The sky is dark, with a few faint stars visible. In the foreground, the silhouettes of pine trees are visible, framing the scene. In the background, a mountain range is visible under the aurora.

**Any question?**