Sunny with a chance of electron precipitation: *Space Weather research in Alaska and at Toolik*

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With many, many contributions from UAF and elsewhere

Jason Ahrns, 2011

What's up with "Space Weather"?

AGU ADVANCING EARTH AND SPACE SCIENCE

RENE

Space Weather Quarterly

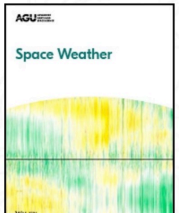
A digest with select articles from the latest issue of the AGU journal Space Weather, a gold open-access journal publishing original research articles and commentaries devoted to understanding and forecasting space weather.

FROM THE EDITORS | RESEARCH ARTICLES | SPECIAL COLLECTION

FROM THE EDITORS

Machine-Learning Research in the Space Weather Journal: Prospects, Scope and Limitations

Manuscripts based on machine-learning techniques have significantly increased in Space Weather over the past few years. We discuss which manuscripts are within the journal's scope and emphasize that manuscripts focusing purely on a forecasting technique (rather than on understanding and forecasting a



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97th AMS Annual Meeting | 22–26 January 2017 | Seattle, WA

14th Conference on Space Weather

VIEW IN CONFERENCE PROGRAM

Presentation Topics

The theme for the 2016 AMS Annual Meeting, "**Observations Lead the Way,' weaves the many parts of AMS core**". Following this theme, the Conference on Space Weather will solicit papers for the following sessions

Session 1: "Moving the Space Weather Action Plan (SWAP) Forward" This session is focused on progress being made by the federal agencies as well as the commercial and academic sector in carrying out OSTP's recently released Space Weather Action Plan (SWAP).

EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

NATIONAL SPACE WEATHER STRATEGY AND ACTION PLAN

Product of the

SPACE WEATHER OPERATIONS, RESEARCH, and MITIGATION WORKING GROUP

SPACE WEATHER, SECURITY, and HAZARDS SUBCOMMITTEE

COMMITTEE ON HOMELAND and NATIONAL SECURITY

of the

NATIONAL SCIENCE & TECHNOLOGY COUNCIL

March 2019

NOAA | NATIONAL WEATHER SERVICE

SPACE WEATHER PREDICTION CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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Where does Space Weather happen?

Everywhere between the Sun and the Earth

A US National Initiative

- The Strategy and Action Plan seeks to achieve three objectives, each supported by a set of high-level actions, to enhance the Nation's preparedness for space weather events:

1. Enhance the Protection of National Security, Homeland Security, and Commercial Assets and Operations against the Effects of Space Weather;
2. Develop and Disseminate Accurate and Timely Space Weather Characterization and Forecasts; and
3. Establish Plans and Procedures for Responding to and Recovering from Space Weather Events.

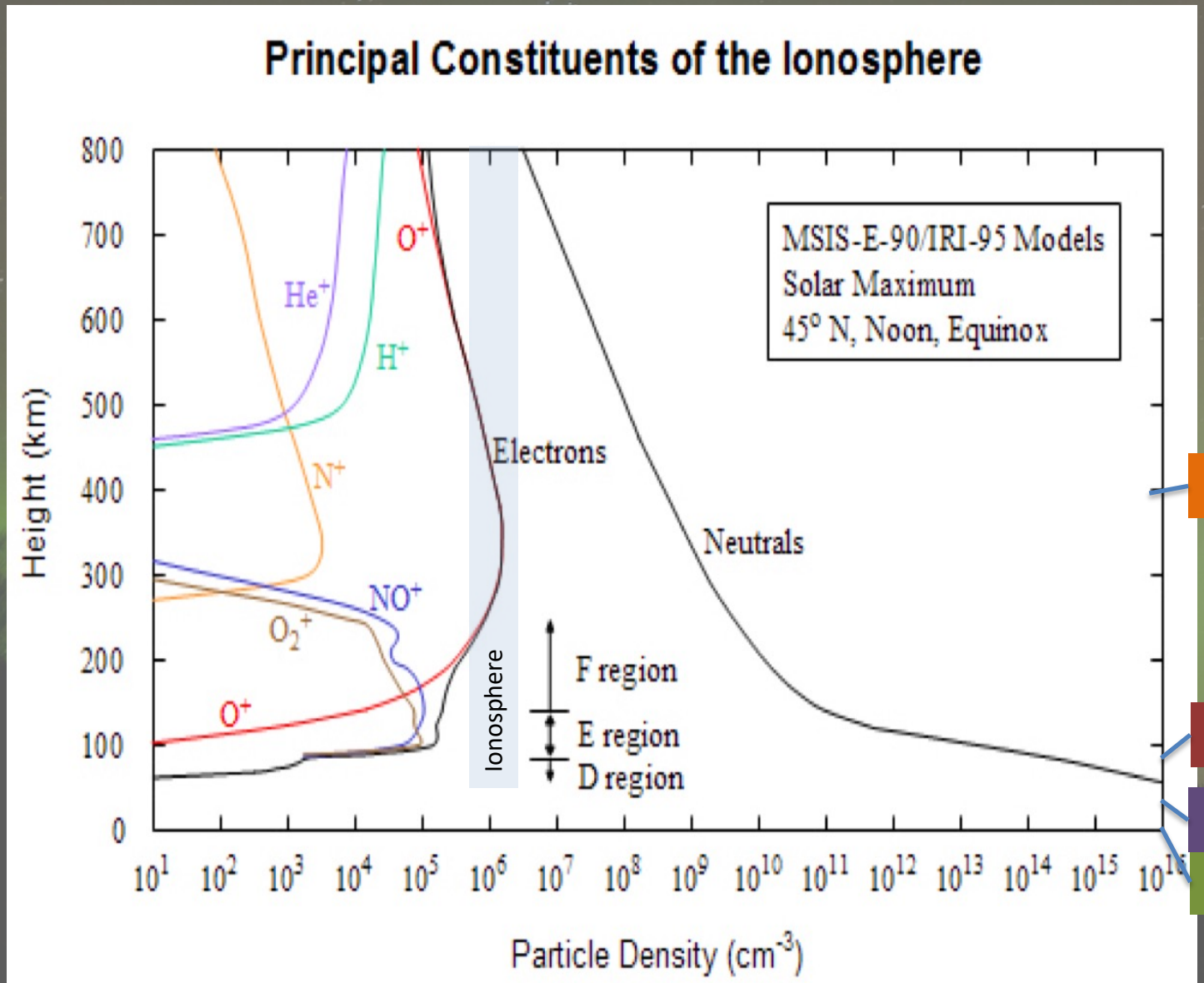
There are two main types of infrastructure that are impacted: **satellites** and **the power grid**

Effects

Communications & Trajectories

Geomagnetically induced currents (GIC) leading to power disruption

Where does space begin?



Thermosphere (> 90km)

Mesosphere (30-90km)

Stratosphere (11-30km)

Troposphere (0-11km)

The bigger picture
Solar Wind

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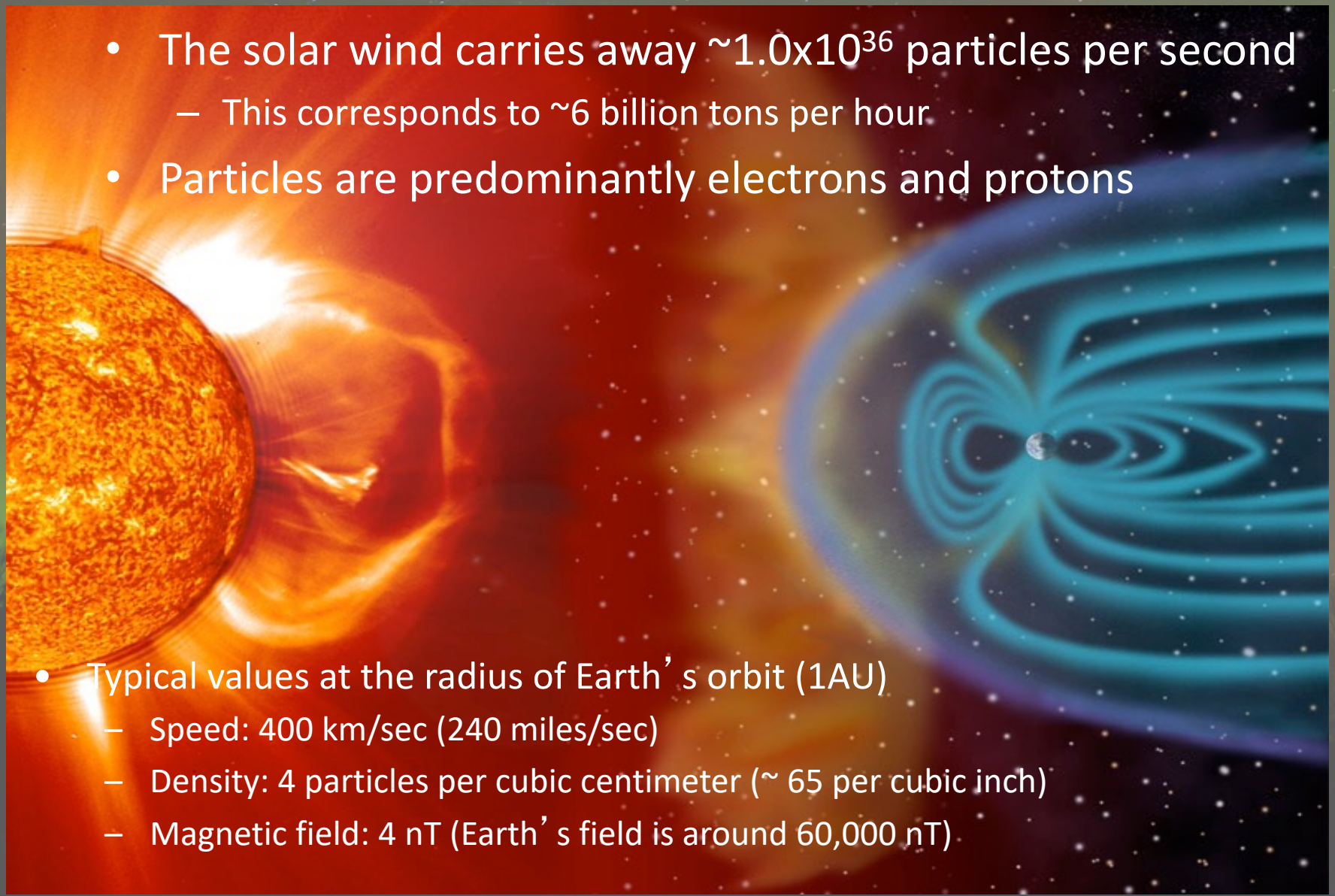
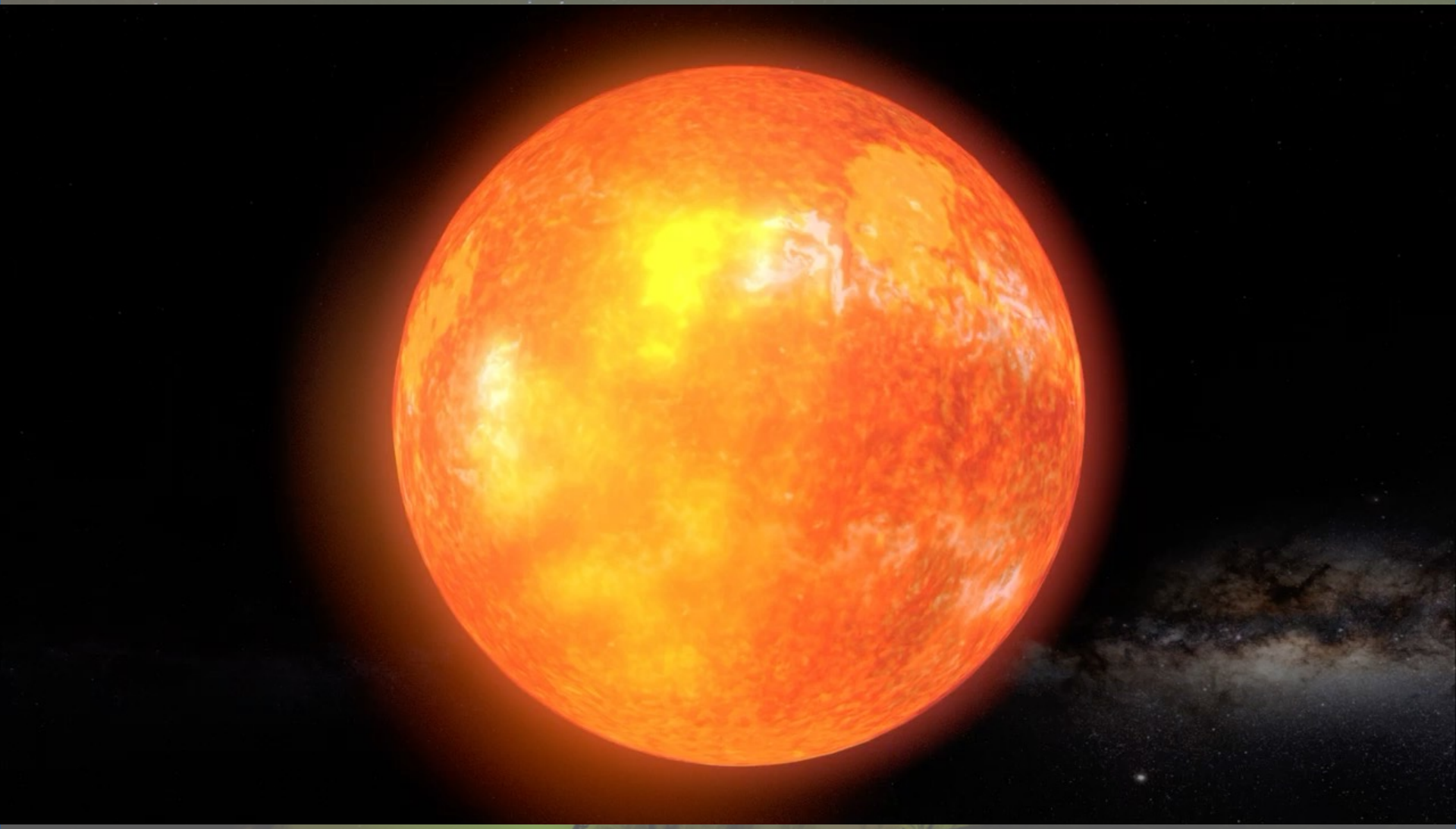


- The solar wind carries away ~1.0×10^{36} particles per second
  - This corresponds to ~6 billion tons per hour
- Particles are predominantly electrons and protons

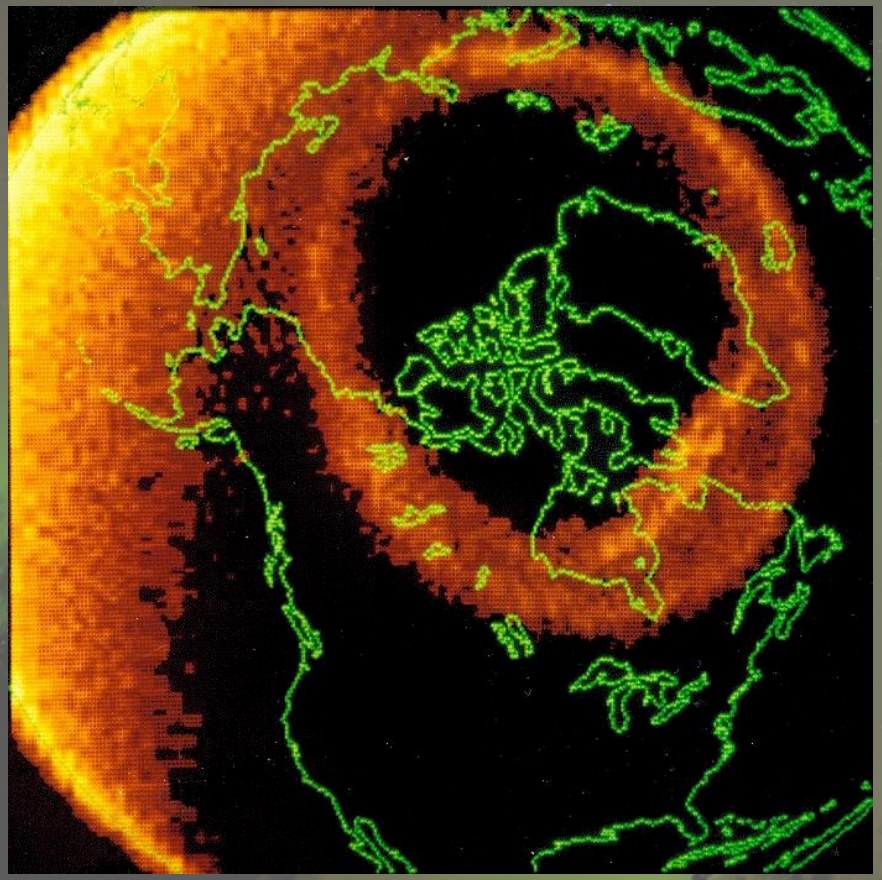
- Typical values at the radius of Earth's orbit (1AU)
  - Speed: 400 km/sec (240 miles/sec)
  - Density: 4 particles per cubic centimeter (~ 65 per cubic inch)
  - Magnetic field: 4 nT (Earth's field is around 60,000 nT)

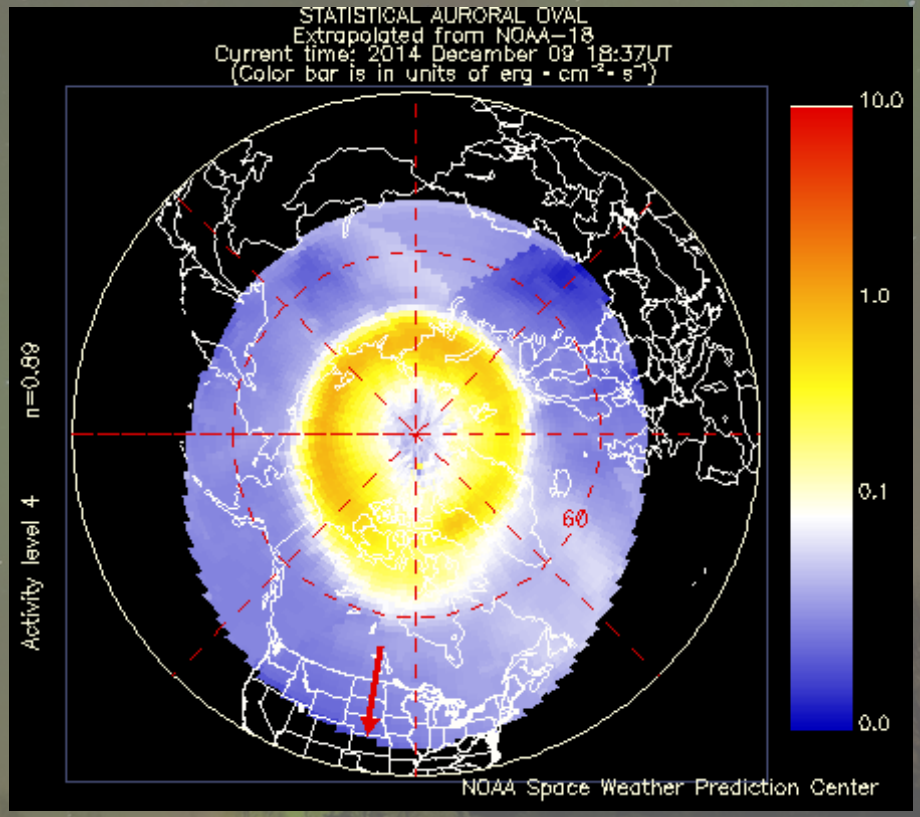
Solar wind influences



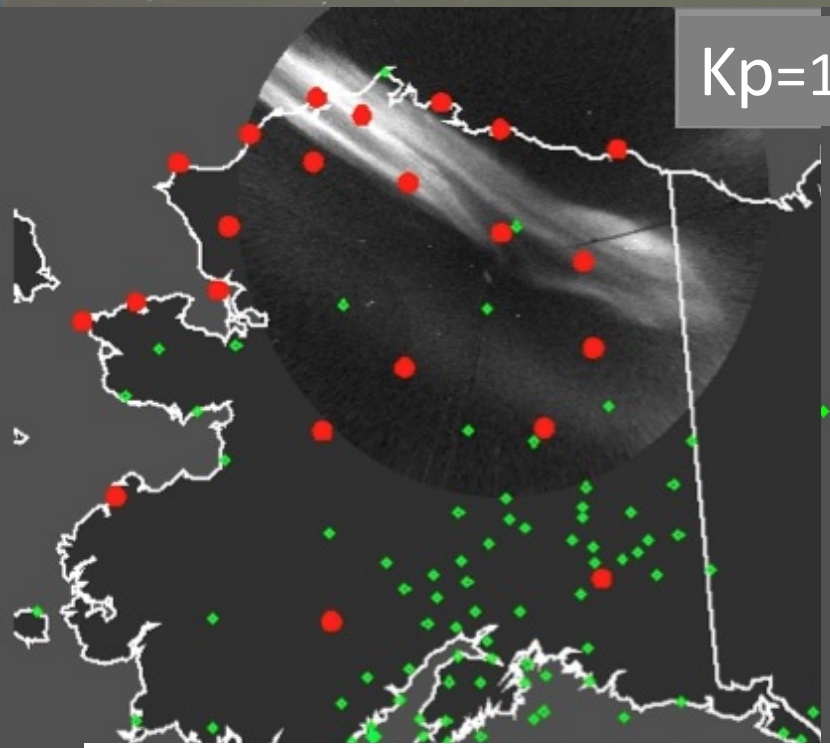
Polar regions receive the most energy in Space Weather

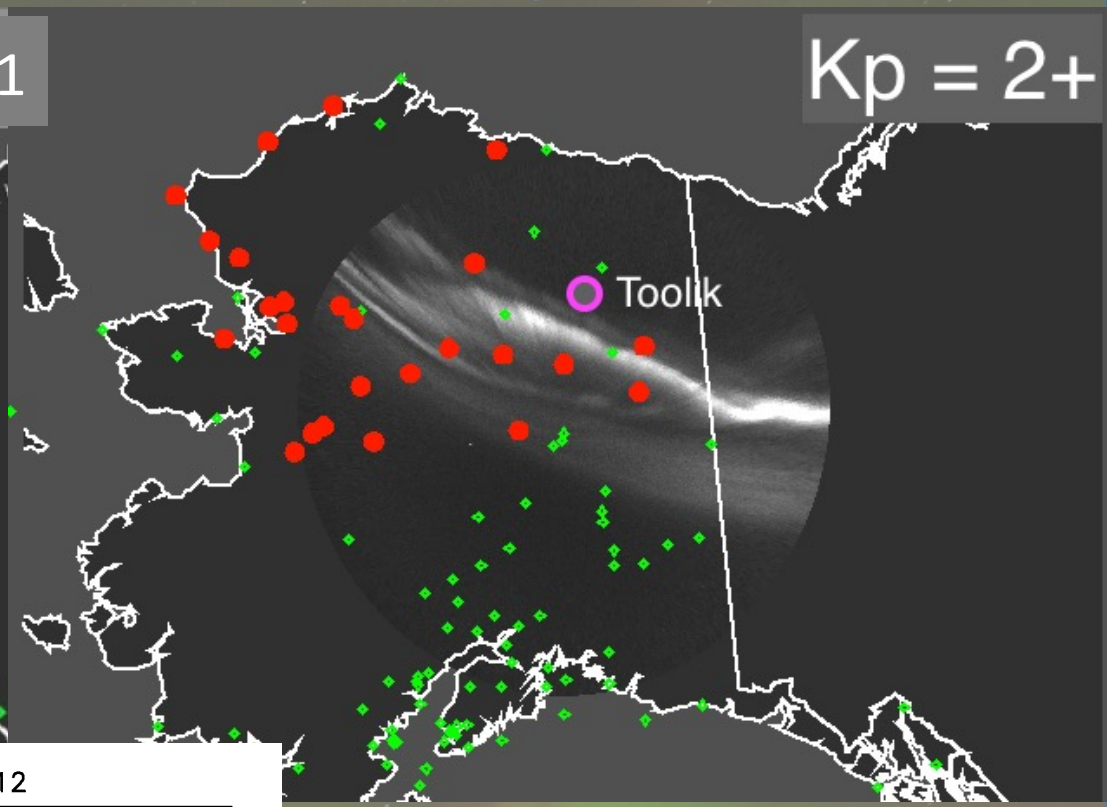
Auaras occur in an oval region around the geo***MAGNETIC*** pole

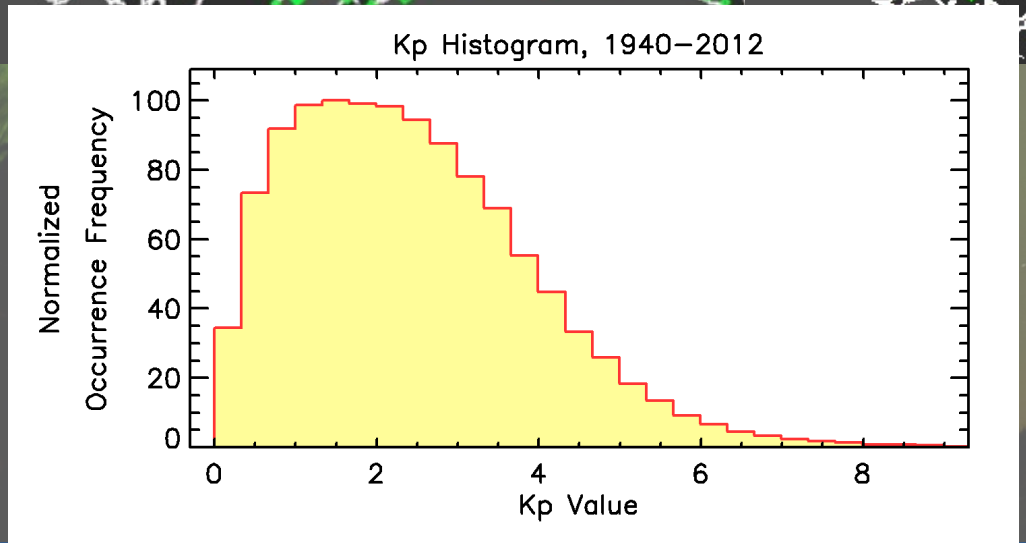




Why Alaska? Why Toolik?



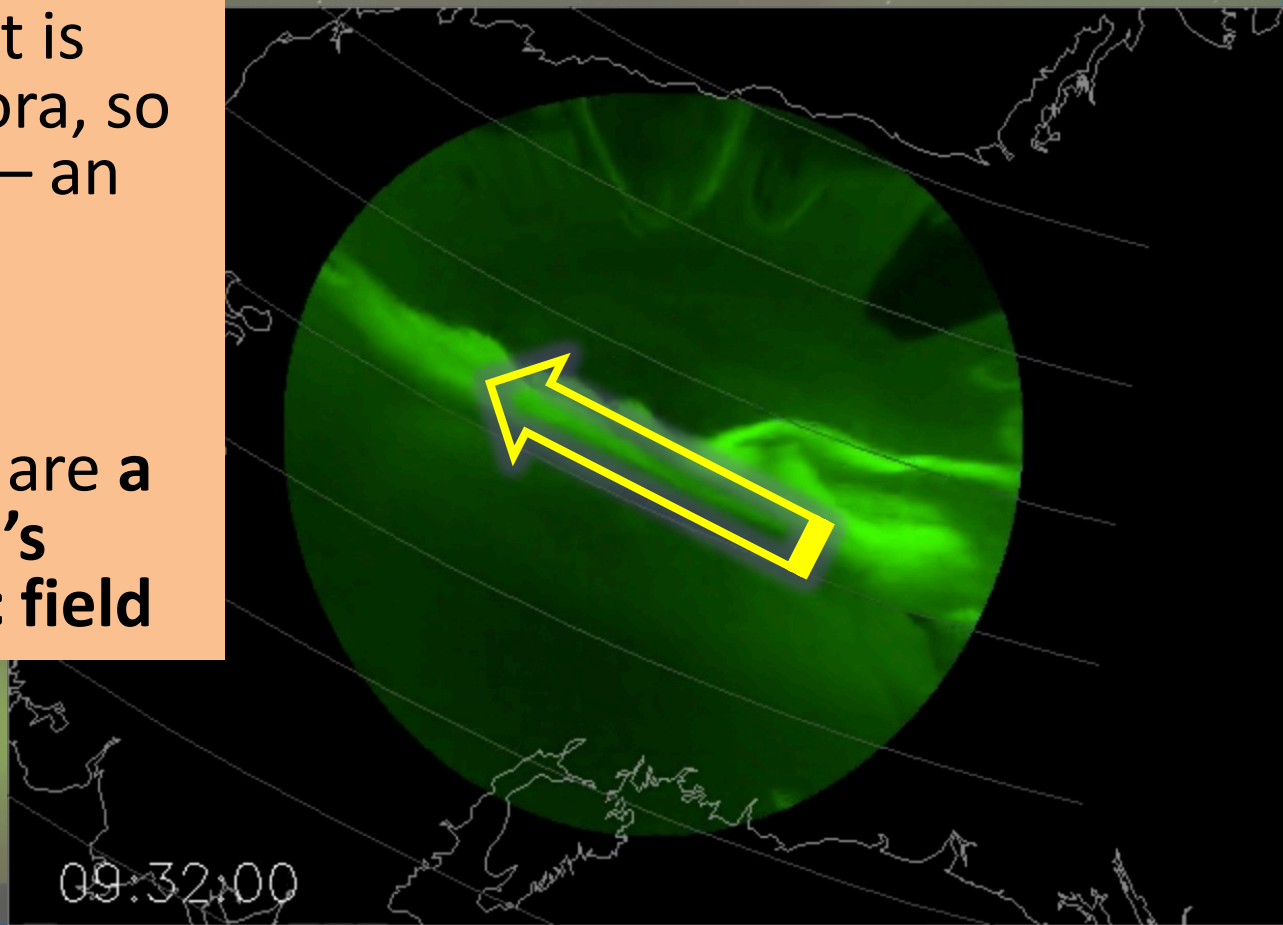




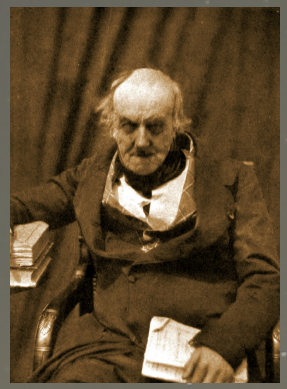
~ Half of all activity will occur at latitudes that match Toolik Lake

Auroral Electrojets

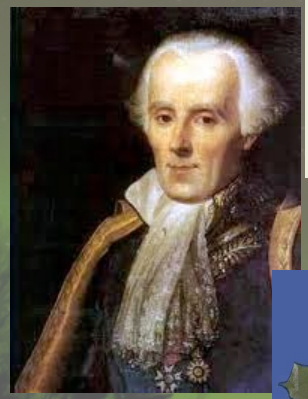
- The voltages and changes in electrical conductivity in the ionosphere can create strong currents.
- This type of current is specific to the aurora, so has it's own name – an auroral electrojet
- Strong events can produce magnetic perturbations that are **a few % of the Earth's constant magnetic field**



How to make a magnetic field? Drive a current!



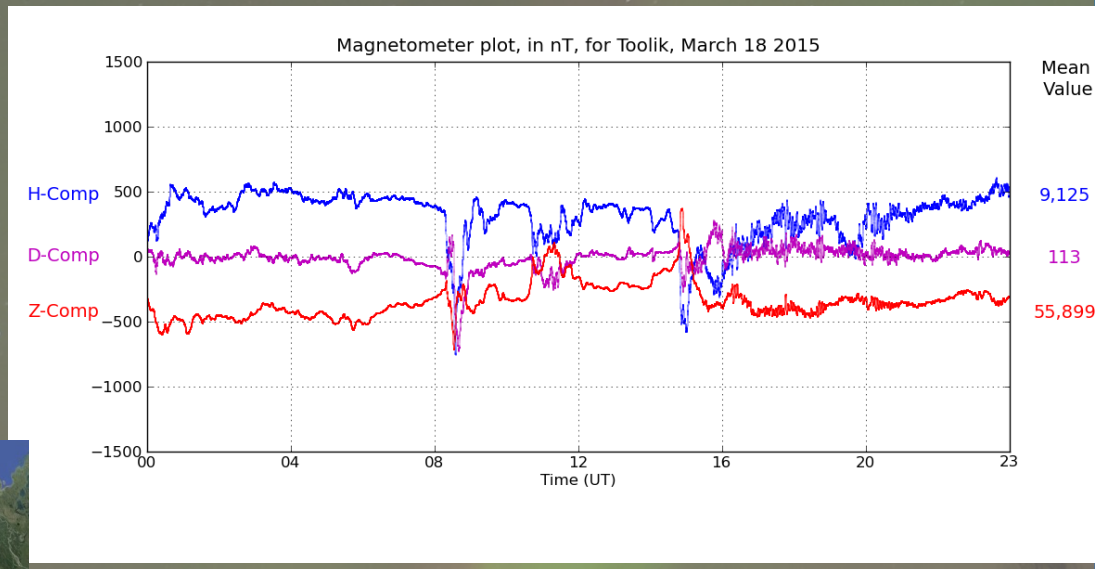
Jean-Babtiste Biot
1774-1862

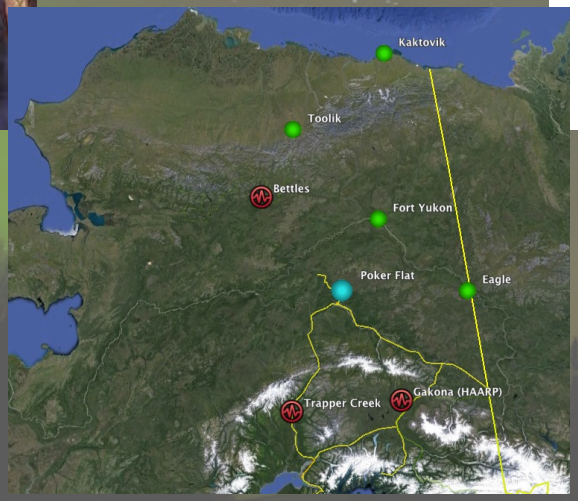


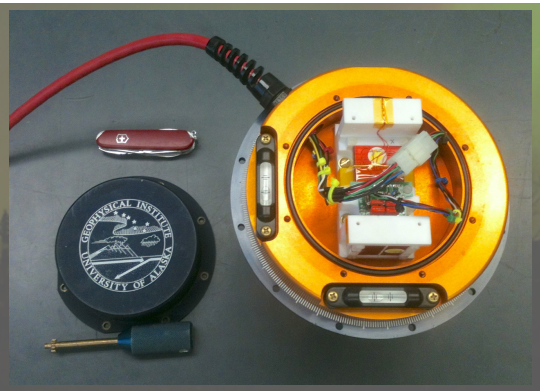
Felix Savart
1791-1841

Biot-Savart Law: A (net) electrical current produces a magnetic field. The strength of the magnetic field is proportional to the current and falls off with the distance from the current.

The Auroral Electrojet creates strong magnetic perturbations in the auroral zone during active storms







Induced currents - Consequences

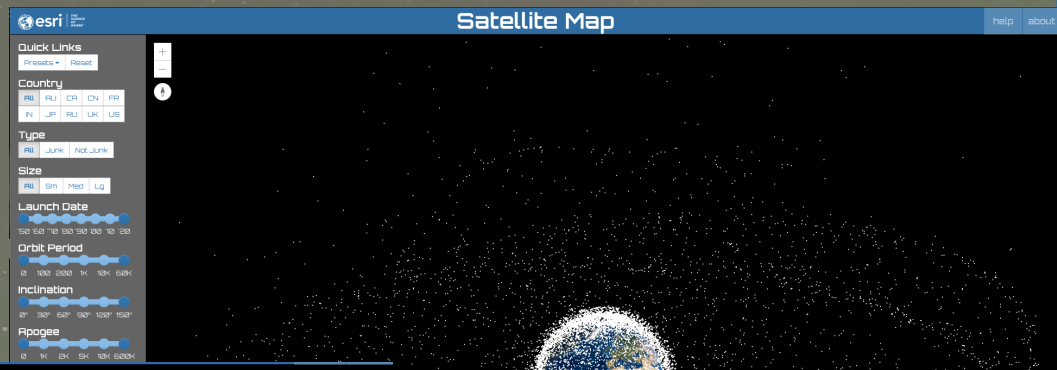
- March 13th, 1989 – Hydro-Quebec Power Outage
  - GICs generated from an intense solar flare caused a 9 hour power outage in the power grid operated by Hydro-Quebec
- August 1989 – Toronto Stock Exchange Halt
  - GICs generated from another intense solar flare (stronger than the March storm) affected microchips in computer systems associated with the Toronto Stock Exchange causing a halt in trading

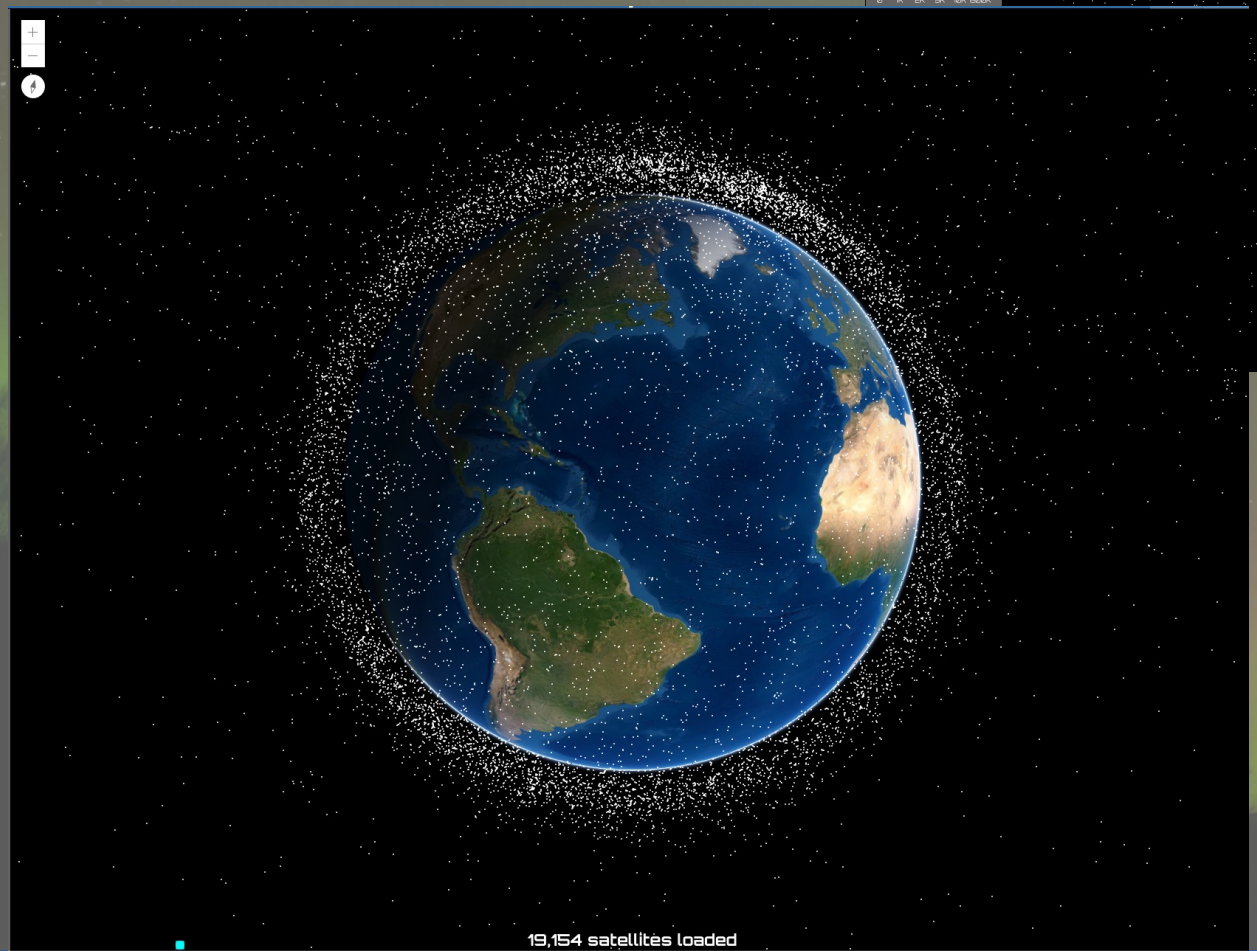
Figure: Picture showing real transformer damage in New Jersey Public Service Electric and Gas Company transformer due to the March 13, 1989 storm.

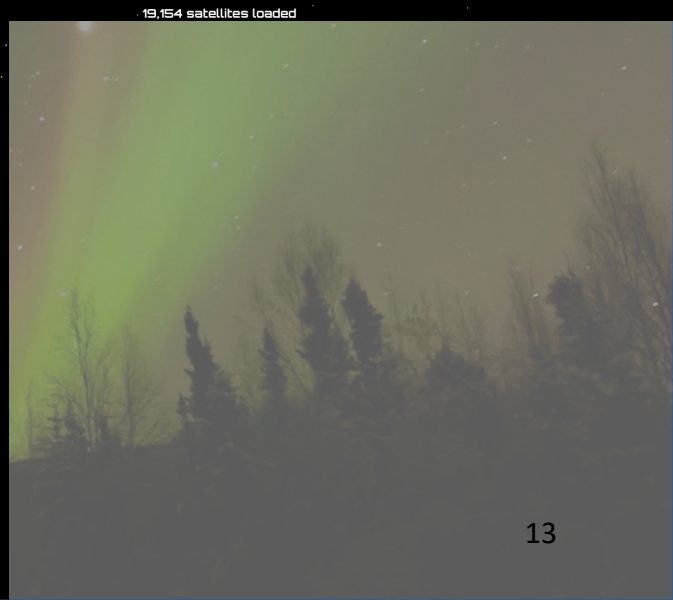
GIC = Geomagnetically Induced Current

Satellites

https://maps.esri.com/rc/sat2/index.html







The dynamic neutral atmosphere

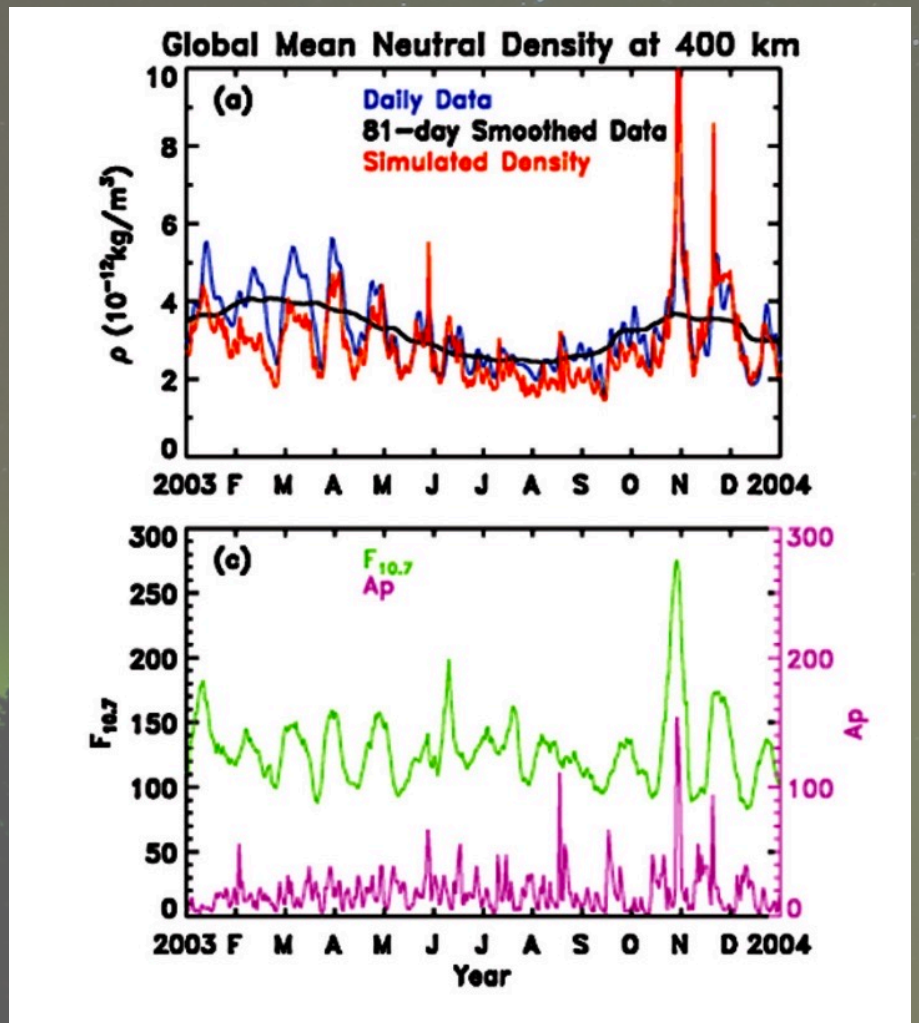
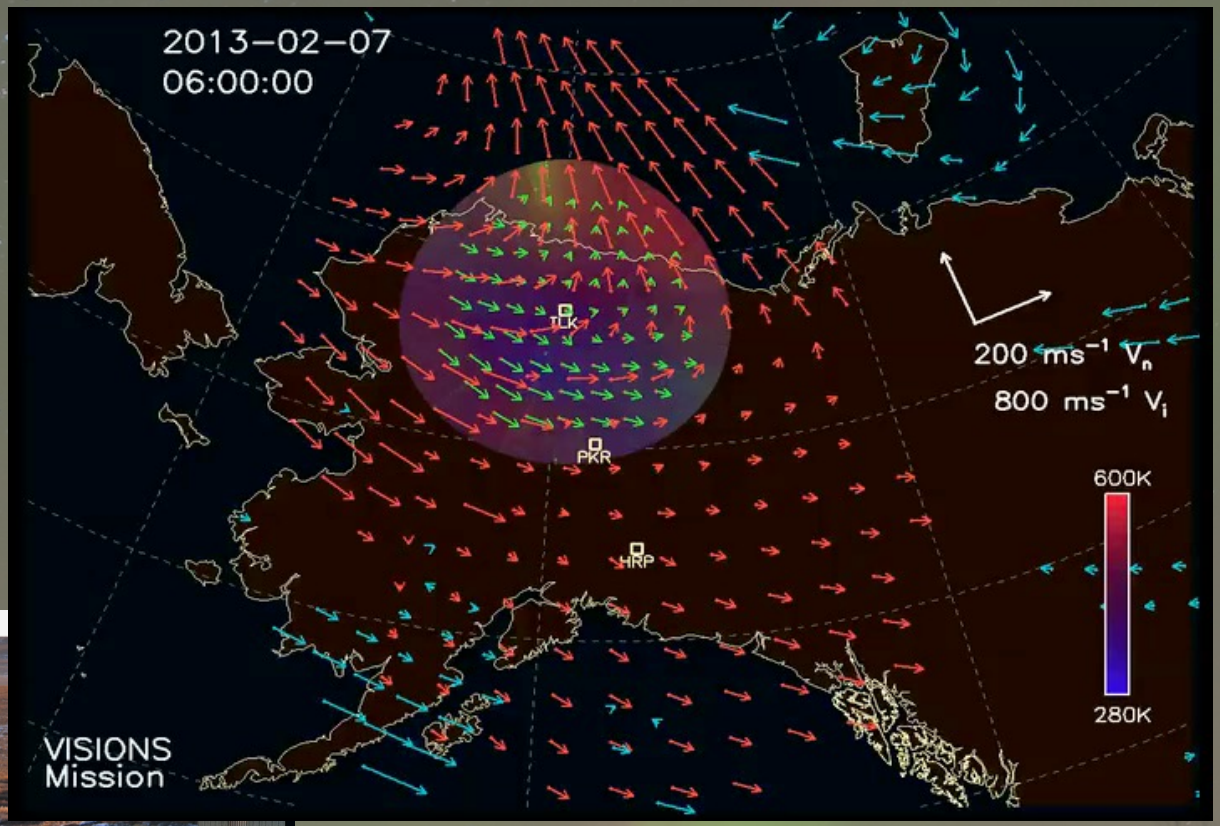


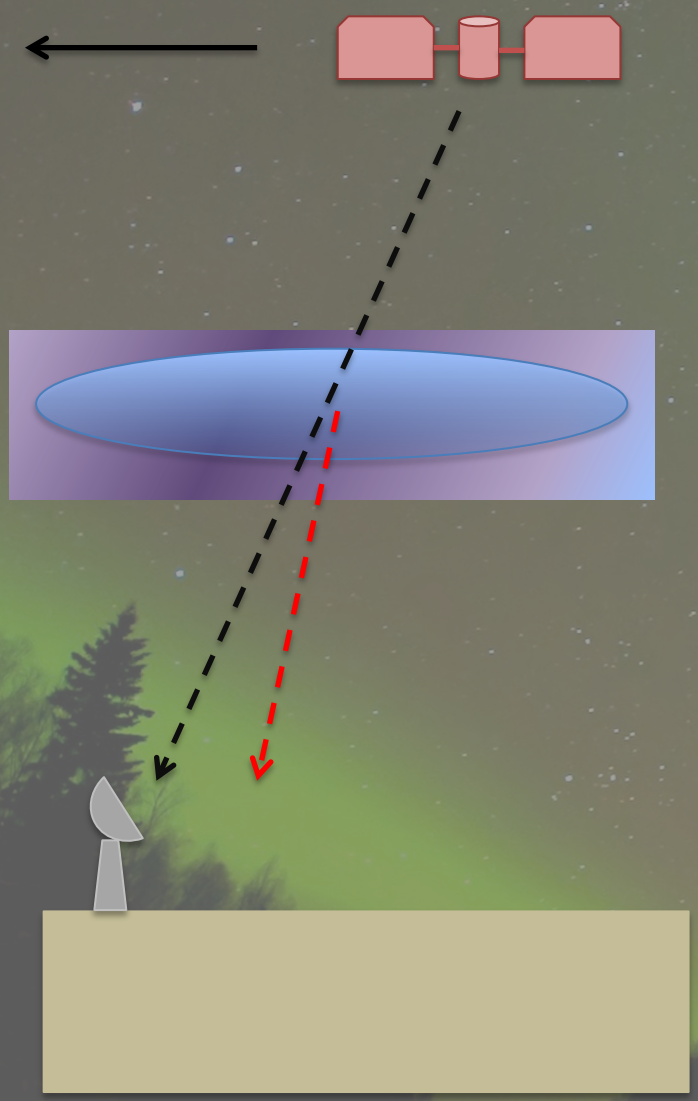
Figure: Qian & Solomon, Space Sci Rev (2012) 168:147–173.

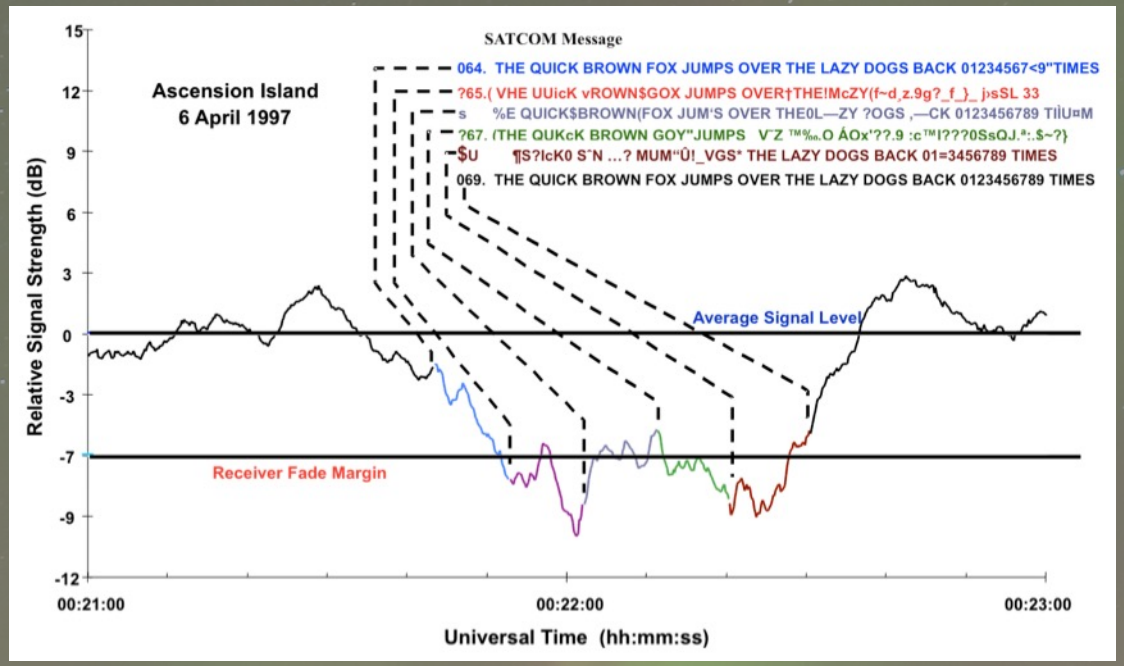
Currents and active ultraviolet light from Sun can change the density of the neutral particles in the upper atmosphere

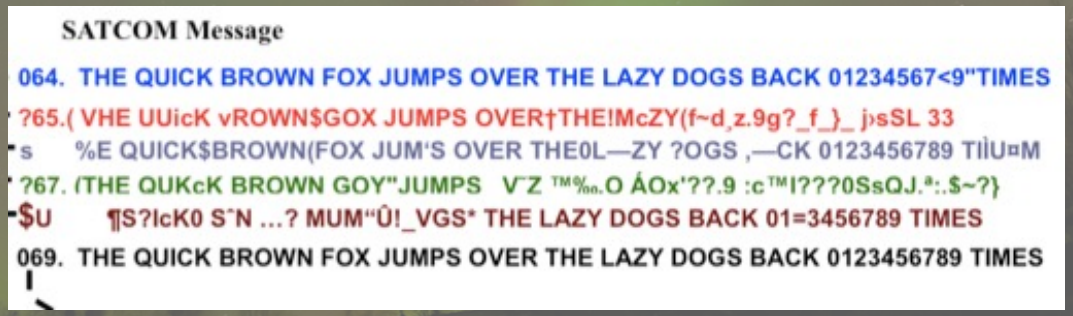
Upper atmospheric winds



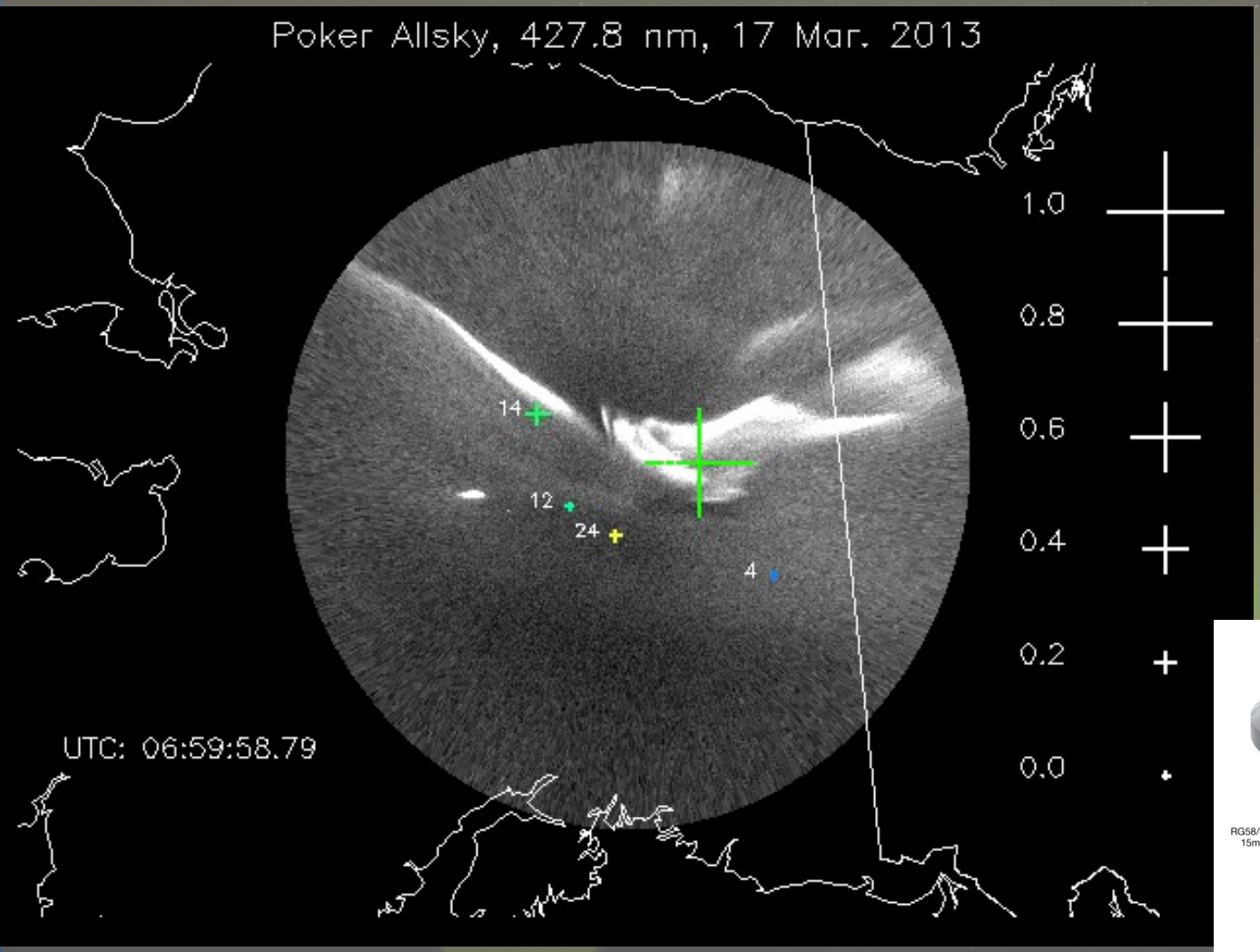
Plasma Effects on Communication





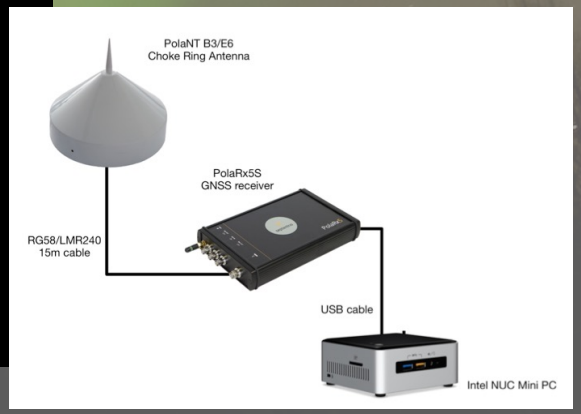


Combined Data
Optics & GPS scintilation



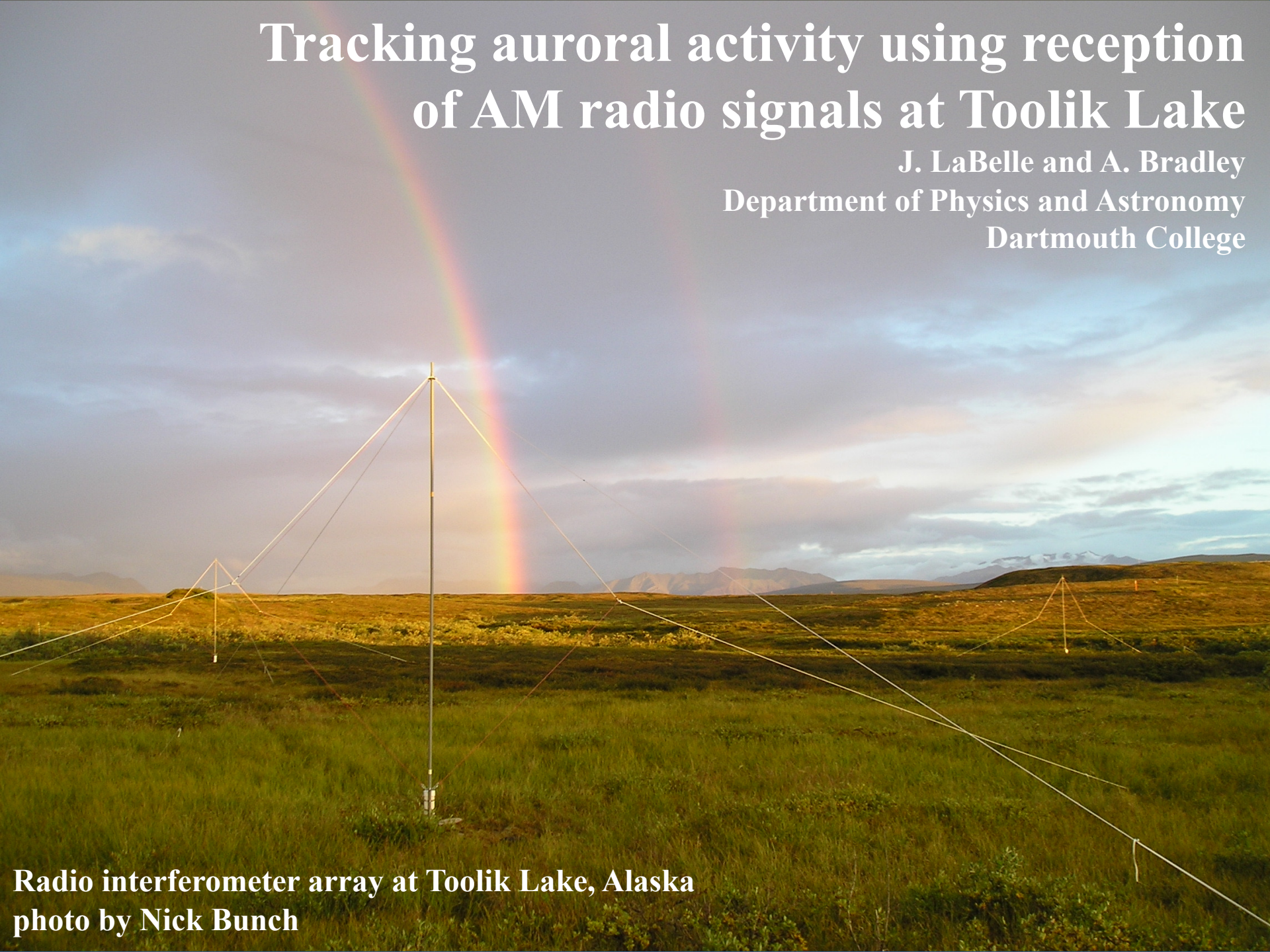
Since 2010

Coming in 2023



Tracking auroral activity using reception of AM radio signals at Toolik Lake

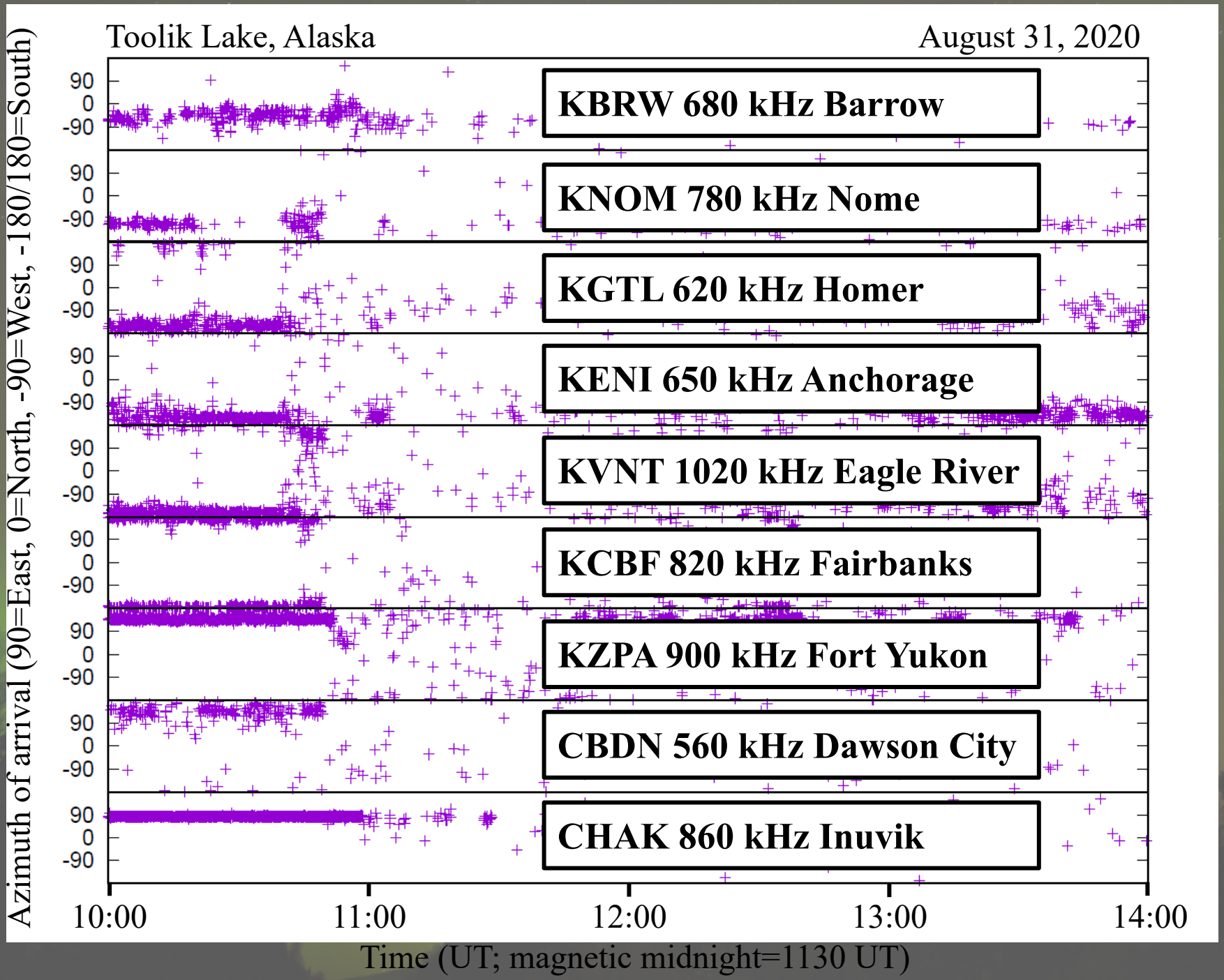
J. LaBelle and A. Bradley
Department of Physics and Astronomy
Dartmouth College

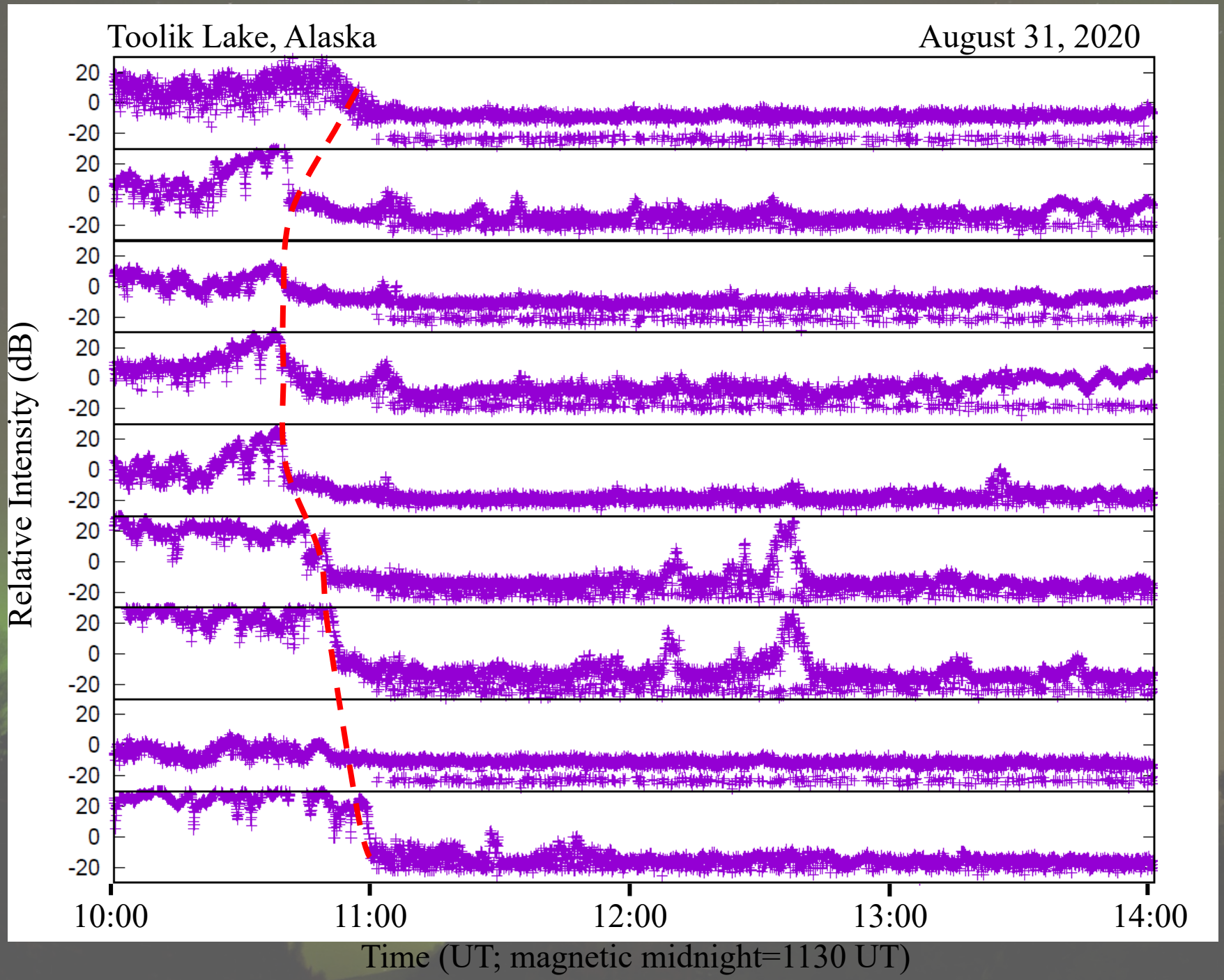


Radio interferometer array at Toolik Lake, Alaska
photo by Nick Bunch

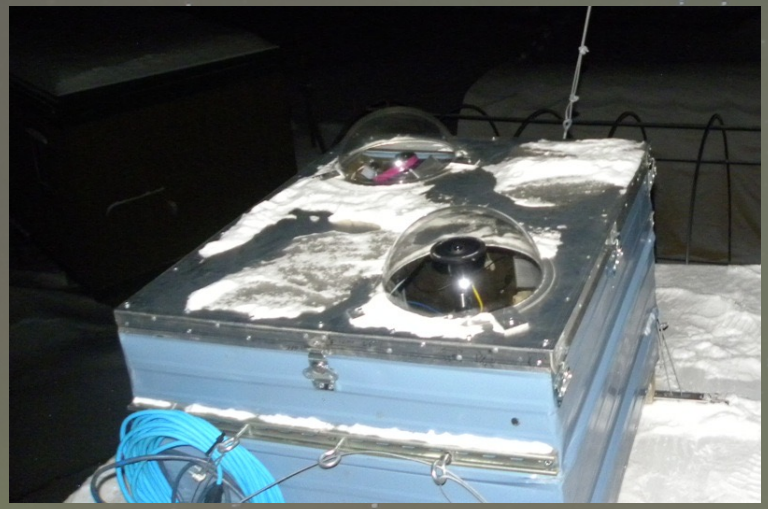
Paths between Toolik Lake and selected AM transmitters in the Alaska/Yukon region (~five more transmitters, not shown, are received from Anchorage/Fairbanks)

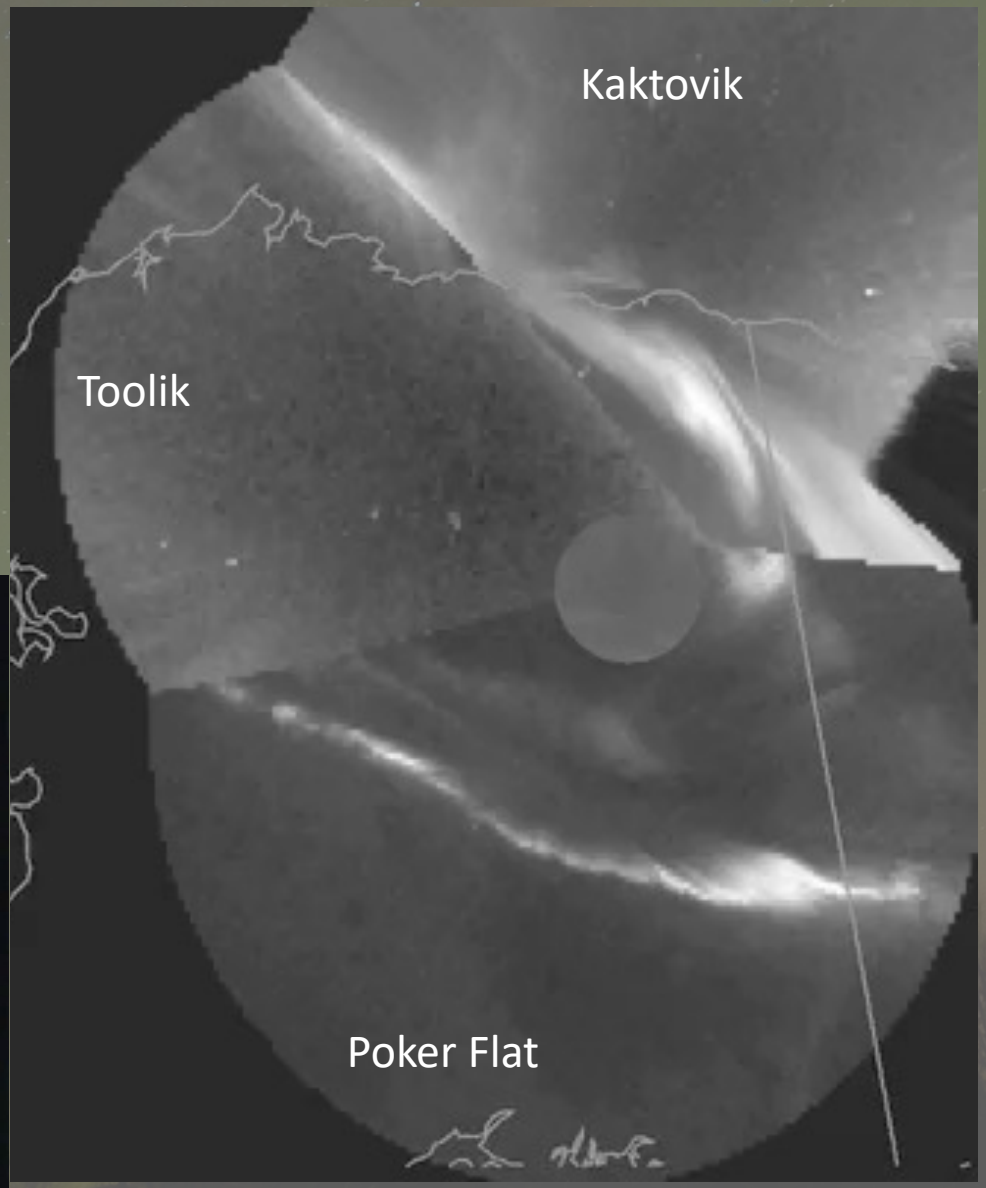
These radiate like spokes on a wheel away from Toolik Lake. On the next plot, received directions of arrival of the signals are shown in order, west to south to east. On the subsequent plot, the intensities of the same signals are shown.


Toolik Lake, Alaska
August 31, 2020
Azimuth of arrival (90=East, 0=North, -90=West, -180/180=South)
90
0
-90
KBRW 680 kHz Barrow
KNOM 780 kHz Nome
KGTL 620 kHz Homer
KENI 650 kHz Anchorage
KVNT 1020 kHz Eagle River
KCBF 820 kHz Fairbanks
KZPA 900 kHz Fort Yukon
CBDN 560 kHz Dawson City
CHAK 860 kHz Inuvik
10:00
11:00
12:00
13:00
14:00
Time (UT; magnetic midnight=1130 UT)


Toolik Lake, Alaska
August 31, 2020
Relative Intensity (dB)
20
0
-20
10:00
11:00
12:00
13:00
14:00
Time (UT; magnetic midnight=1130 UT)

Cameras at Toolik





Summary – Space Weather

- Space weather has the potential to affect billions of dollars of infrastructure
  - Affects civil, commercial and defense operations
- The main risk is a “big event”
  - See e.g. Carrington Event of 1859
- Main focus of research is characterizing the response of the ionosphere and upper atmosphere to predict how our infrastructure will respond.
- It’s a global and international enterprise.

Summary Toolik

- Toolik is a prime site for Space Weather research at UAF and other institutions
  - Dark skies
  - Quiet RF
  - Right latitude for a majority of events
  - Good position for rocket and satellite overflights
- Plans are to continue work and expand when possible
- If there are plans for upgrades, a dedicated optical and RF area would be desireable
  - ”Smurf Hut” is leaky and probably an energy sink
  - Consolodate instrumentation in one area