ICE-PPR Situational Awareness Working Group
11/6/2020 Polar Maritime Technology Update

Dr. Phil McGillivary, USCG PACAREA & Icebreaker Science Liaison
Email: philip.a.mcgillivary@uscg.mil

Jan Mayen Island

Polar Maritime Technology Update

This talk will focus on three key issues identified as significant issues for the Situational Awareness Working Group:

1 – Navigation in GPS-denied environments

- 1.1 – eLORAN
- 1.2 – Diamond quantum magnetometer magnetic anomaly detection positioning

2- Detection and Tracking of Submarines: quantum magnetometers and gravimeters

3 – Improved data acquisition and predictive modeling of ‘Space Weather’ (Auoral disturbances): New satellite data to further predictive modeling

Navigation in GPS-Denied Environments

The problem of GPS spoofing and denial is well-known; technologies for this are readily available COTS online. The methods can be ground or air based with equal efficacy.

Two solutions to GPS interference have been suggested: eLORAN and quantum magnetometry.

In the US, eLORAN will be administered by the US Dep. Of Transportation, and overseen by the USCG. In the UK and Norway, initiatives for installation are being overseen by their Navies initially.

Navigation in GPS-Denied Environments

Key facts about eLORAN

- eLORAN operates at @100kHz: @1000 fold lower than LORAN-C
- eLORAN operates at 1 Million Watts power: >>LORAN-C; $5x10^6$ x >GPS
- eLORAN stations range=@1600 mi: @0% signal loss @1200mi & @6% loss @1600mi
- Due to greater power, eLORAN works well in cities, inside buildings, underground, and underwater to at least 10m depth (which can be improved with modulation) with underwater distance falloff comparable to air
- eLORAN is a completely digital: stations are unmanned and designed for no maintenance for 40+ years (although a central manned operation center is required)
- eLORAN positional accuracy depends on number of overlapping stations, with three stations giving accuracy of +/-8m, but trials have demonstrated accuracy of +/-3.5m (which will not be the case everywhere however).
- eLORAN systems include a cesium clock: timing accuracy from a single station ranges from @1-10nanoseconds

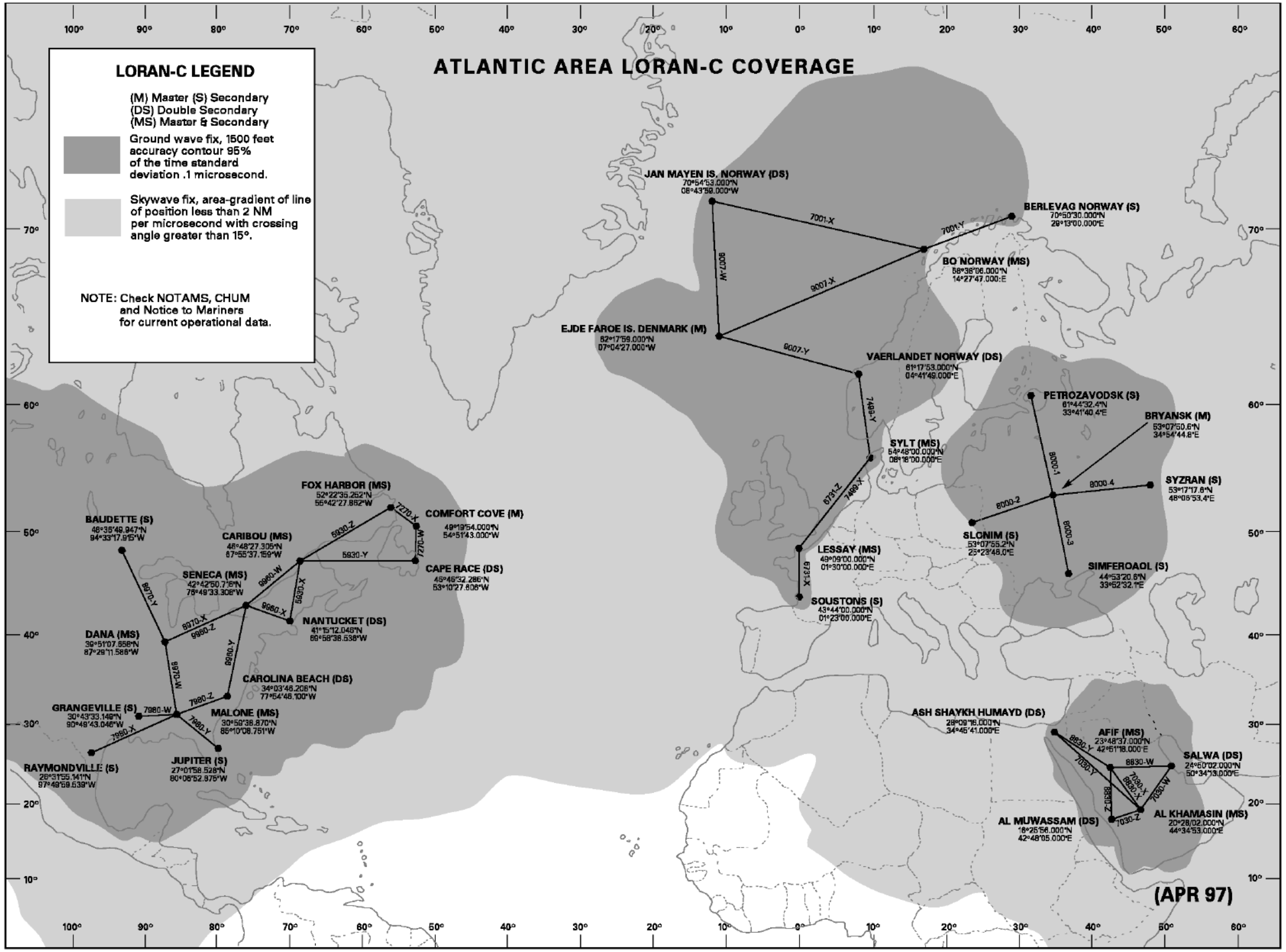
Navigation in GPS-Denied Environments

Key facts about eLORAN

- eLORAN systems can use and need the equivalent antenna system from LORAN-C stations; if unavailable or at new sites a portable antenna system can be used
- eLORAN has a one-way data channel for command and control use (as for unmanned systems) with a bandwidth of >1Kbps, which can be sent to single or multiple systems and is encrypted.
- eLORAN signals are encrypted to prevent access from unauthorized users and as a defense against possible spoofing
- eLORAN systems are not subject to snow, hoarfrost or ice on antennas because of their very low frequency
- eLORAN systems come in a 40' van, but the transmitter components are modular and can be shipped/housed in small containers
- eLORAN receivers include a credit-card sized receiver and similarly sized antenna, with power requirements for both similar to GPS receivers, ie @1 Watt. The cost of both of these systems is <\$50. Thus they are suitable for unmanned systems: in the air, one the surface or underwater.

Navigation in GPS-Denied Environments

North Atlantic LORAN Stations (as of 2006), but missing Station at Cape Farewell, Greenland

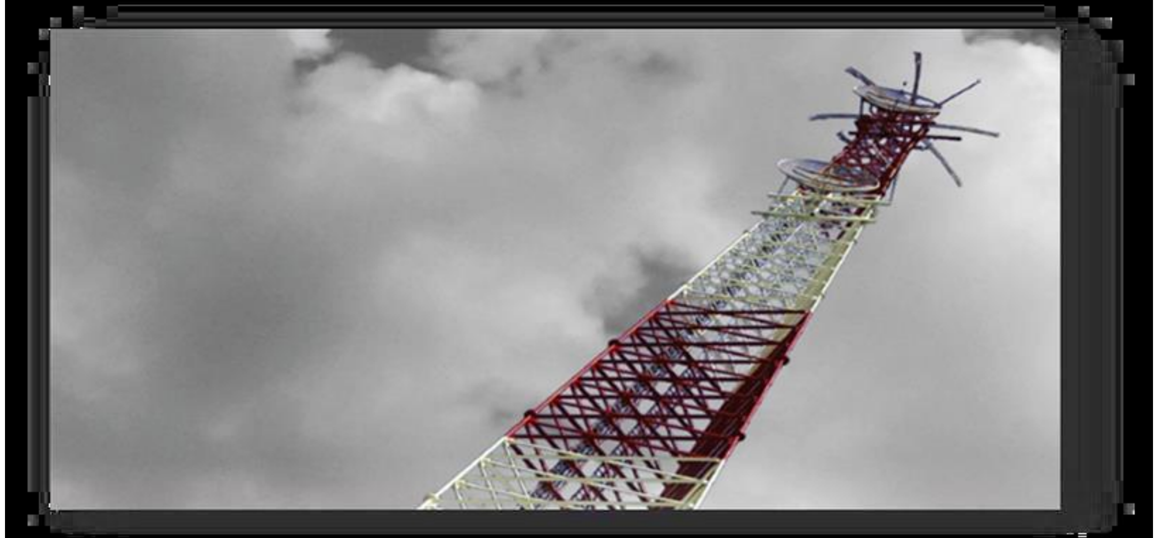


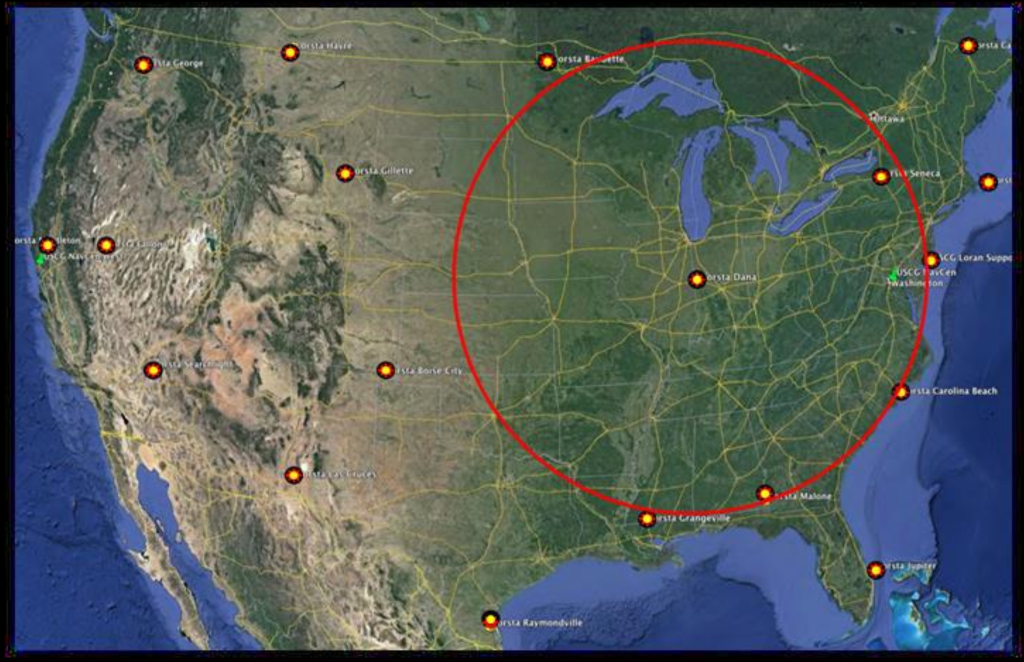
Chapter 10
LORAN CHART COVERAGE

ATLANTIC LORAN C 10-1

Navigation in GPS-Denied Environments

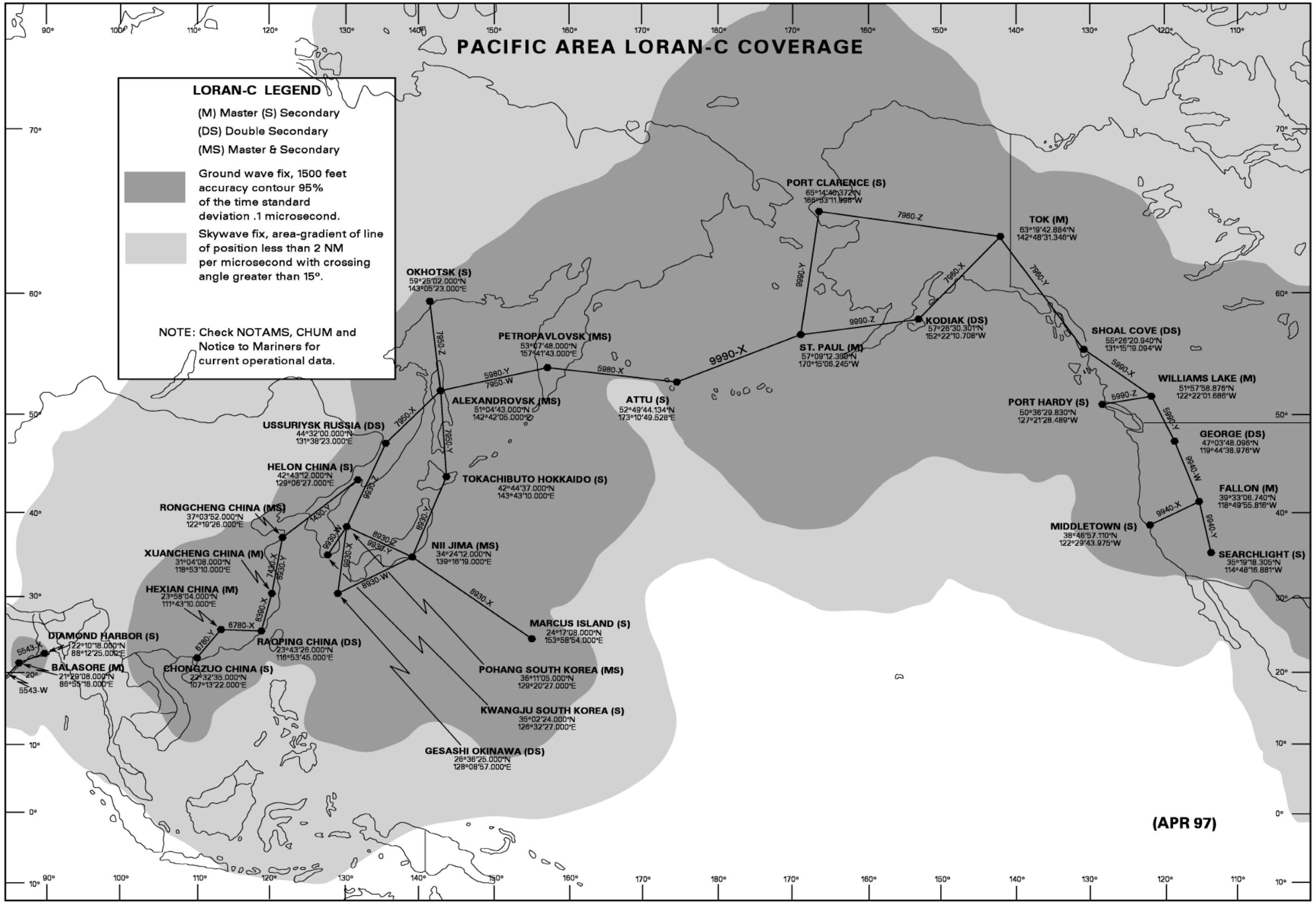
LORAN-C tower and map of 19 US LORAN stations (not including the 4 in Alaska)





Navigation in GPS-Denied Environments

Alaska and North Pacific LORAN Stations



10-2 PACIFIC LORAN C

Navigation in GPS-Denied Environments

eLORAN Receiver module

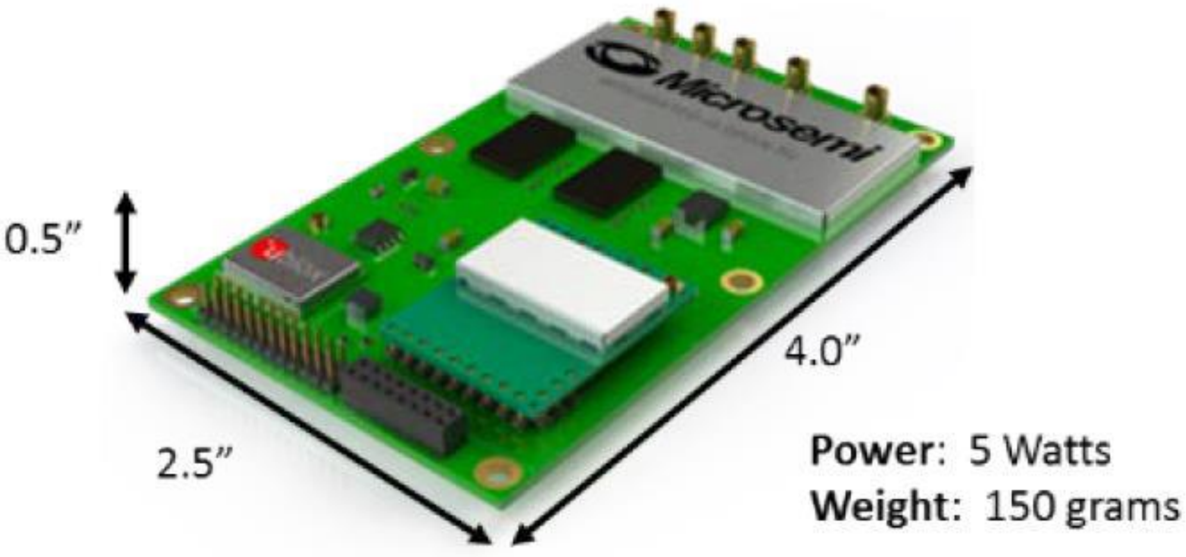
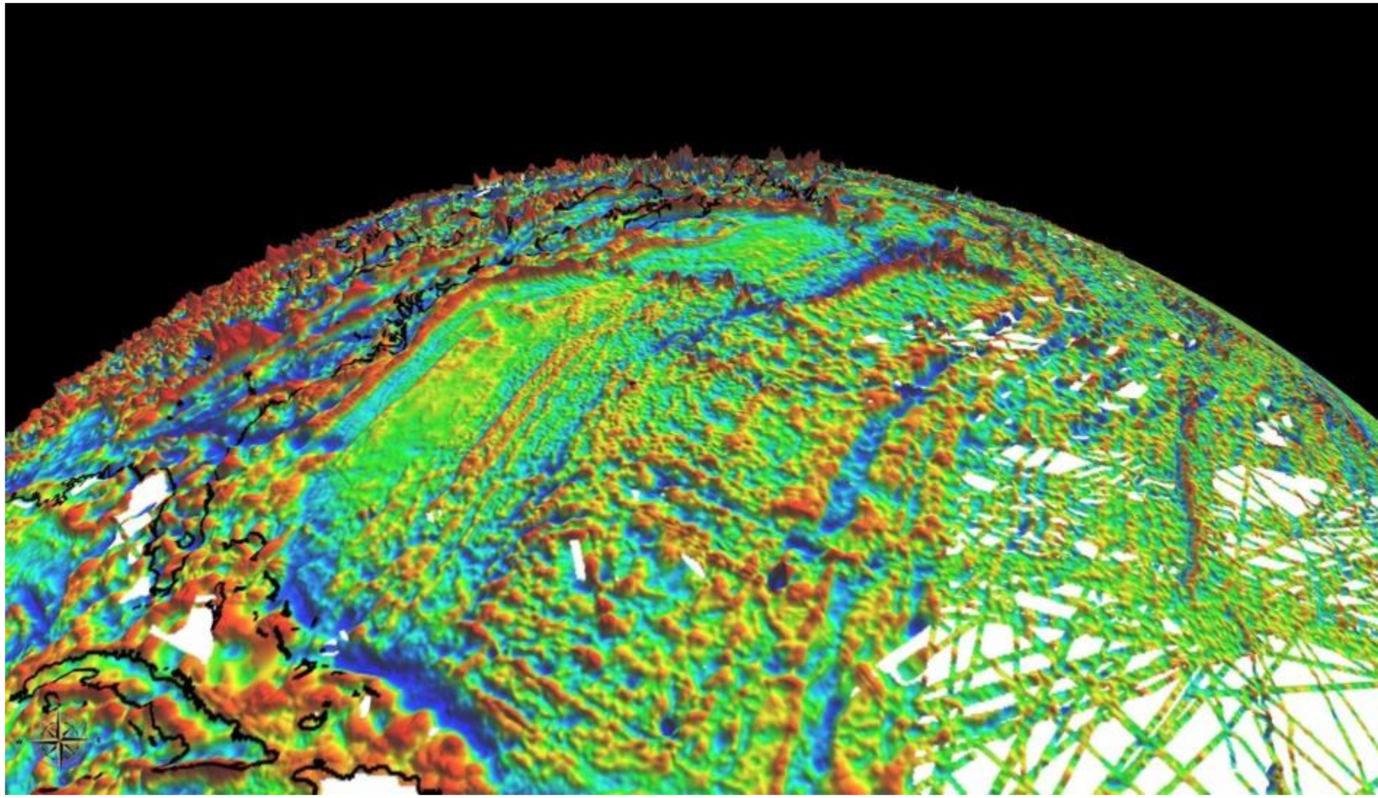


Figure 3.2.1-4. Integrating the eLoran/GPS receiver, eLoran antenna, GPS antenna, and BlueSky technology protects against spoofing and jamming attacks and delivers a hardened GPS signal to end-users that only requires them to change their GPS antenna to the BlueSky PNT antenna.

Navigation in GPS-Denied Environments

Diamond Quantum Magnetometer

World Digital Magnetic Anomaly Map



Improved Modeling of Auroral Disturbances

The key problem with auroral modeling has been data used. While there has been auroral monitoring for over a century, the data, initially collected and compared from several locations on earth, was still ‘point’ sampling.

With the advent of satellites, auroral disturbances were imaged from satellites, however these also amounted to only point sampling initially. Gradually satellite data was able to get 2D imaging of auroral disturbances, but while this allowed for additional mathematical analysis, it has proven largely insufficient for predictive modeling.

Only recently have several ‘mesh network’ small satellites been launched (of 2-3+ satellites) that can properly collect 3D data of auroral disturbances. This is important because the effect on communications, etc., propagates both up and down in the upper atmosphere, and without data on at least three vertical levels and some horizontal data concurrently, models cannot capture what is actually taking place. Now for these recently launched small satellites this data is beginning to become available.