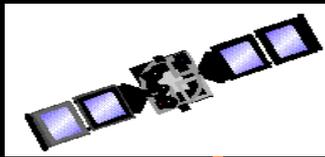


Space Weather Effects on Navigation & Communication Systems



Dr. Bob McCoy
Director, Geophysical Institute
University of Alaska Fairbanks

Ionospheric Effects



SATCOM

250 MHz

Altimetry



10,000 MHz

Reflection



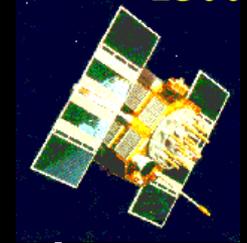
1-20 MHz

HF Comm.
OTH Radar

Scintillation



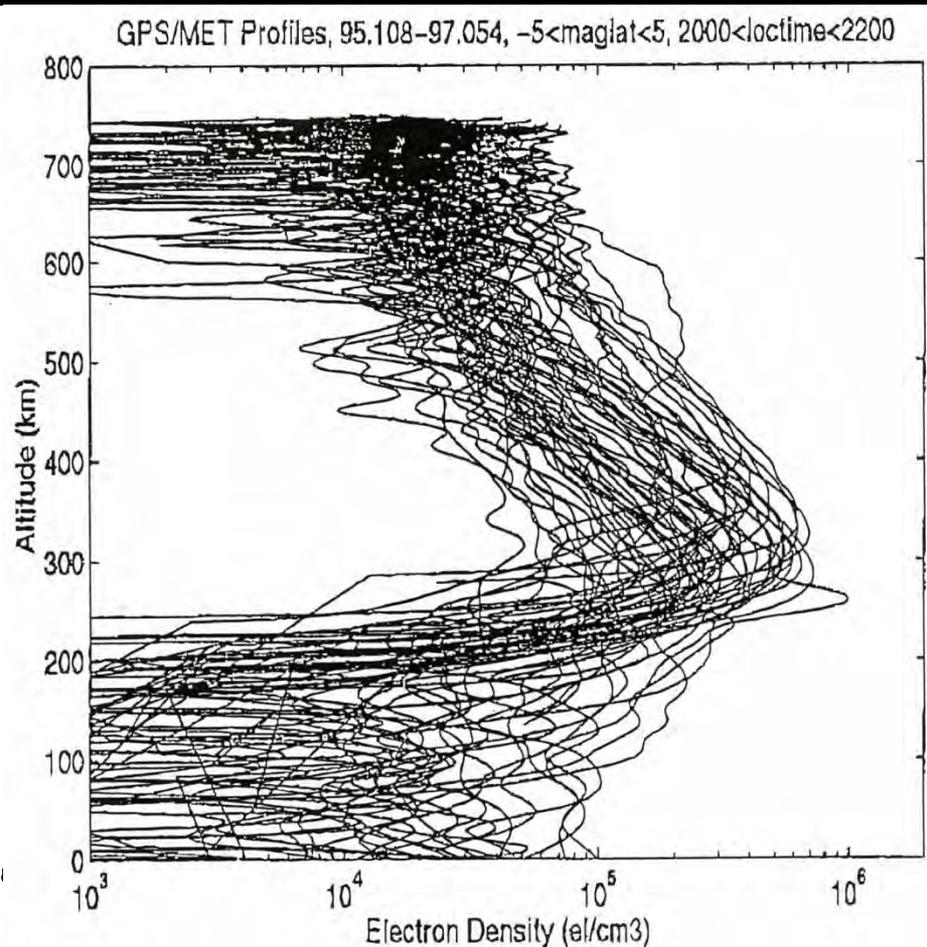
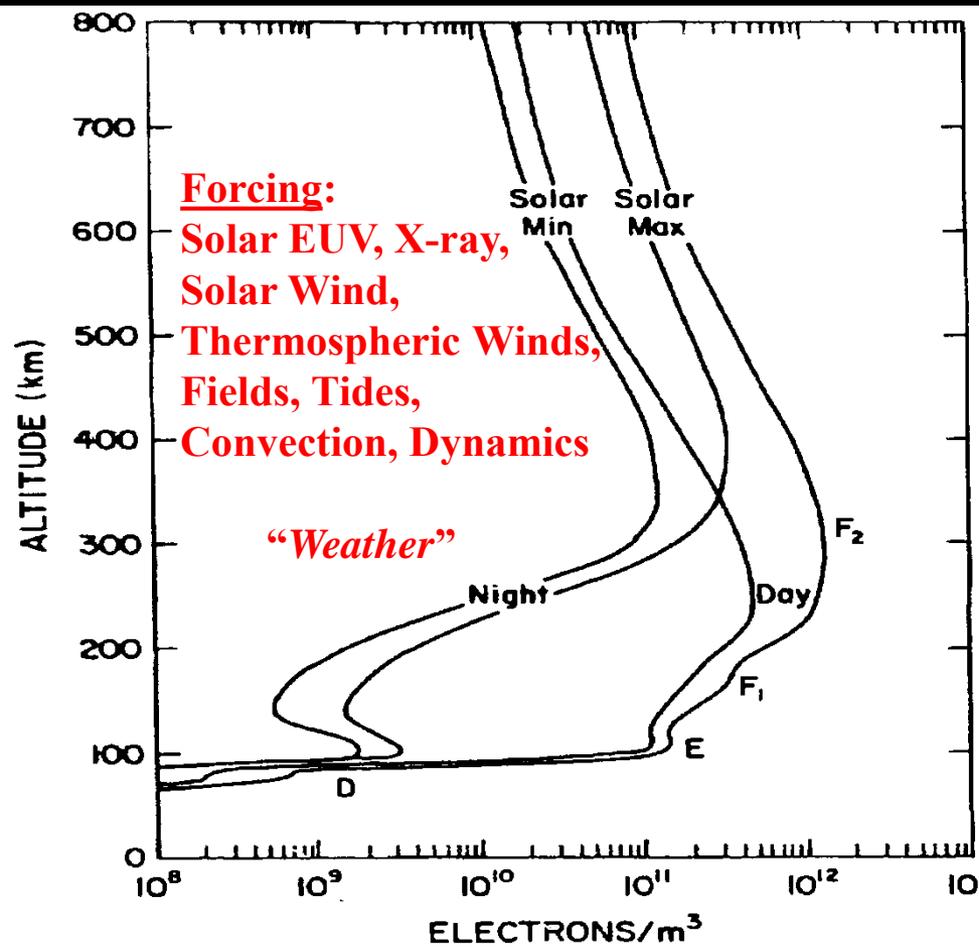
Refraction
Time Delays
Phase Shifts
Faraday Rotation
Dispersion



1500 MHz

GPS



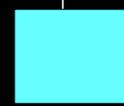
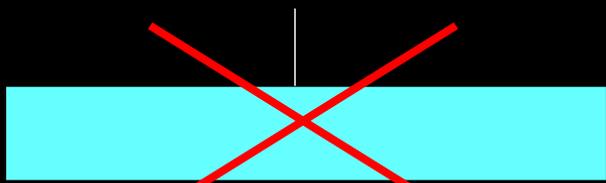


Selective Availability

Ionosphere

Troposphere

Multipath

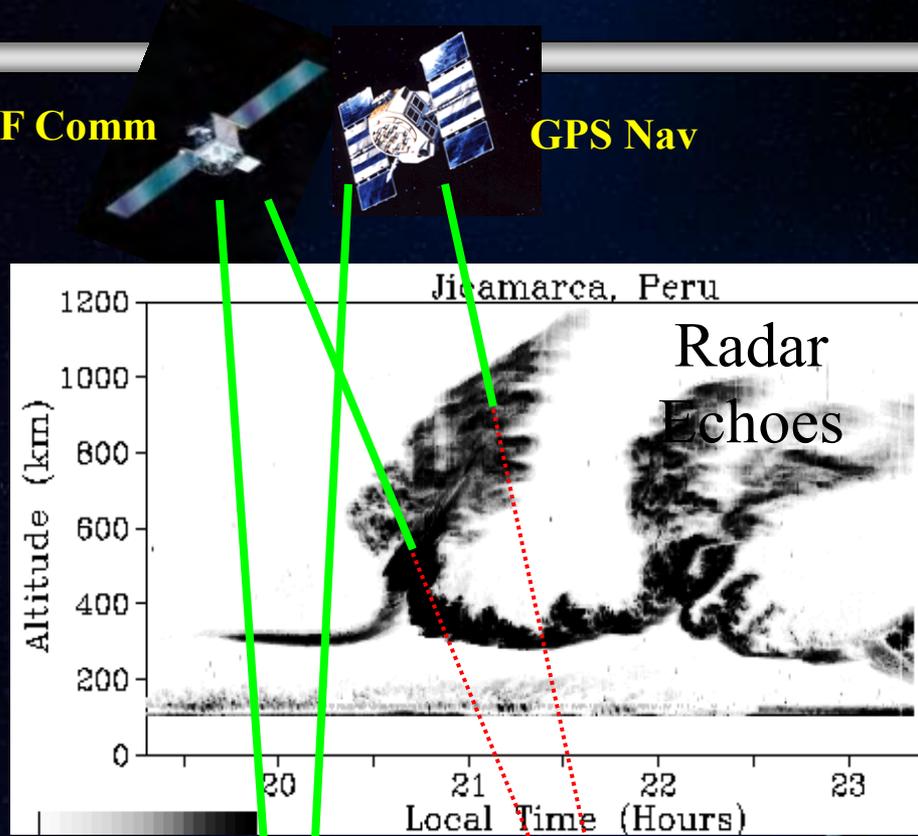
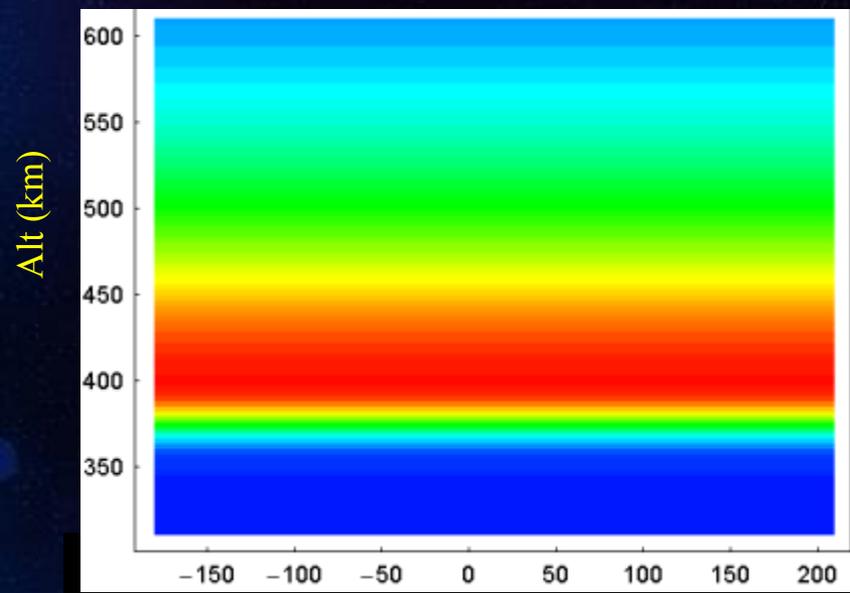


GPS Error Estimates

Orbit & Clock

Noise

Ionospheric Bubbles & Scintillation

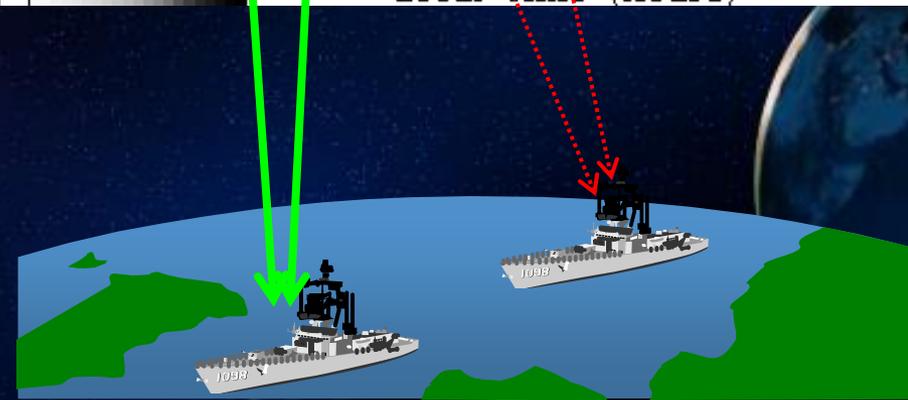
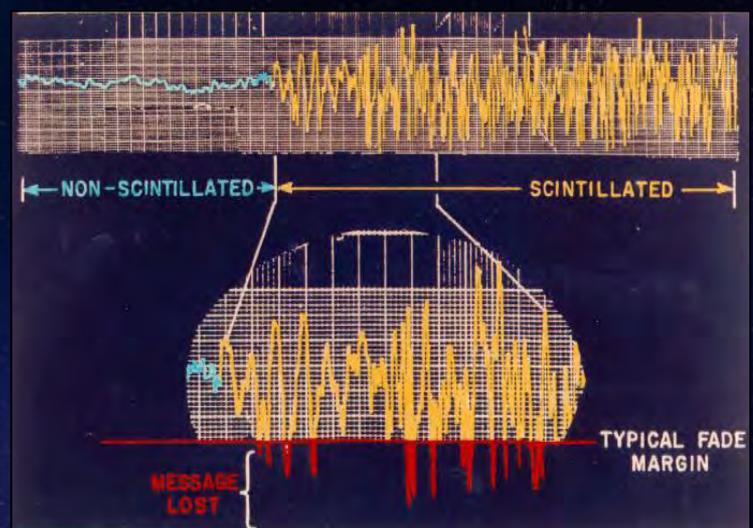


UHF Comm

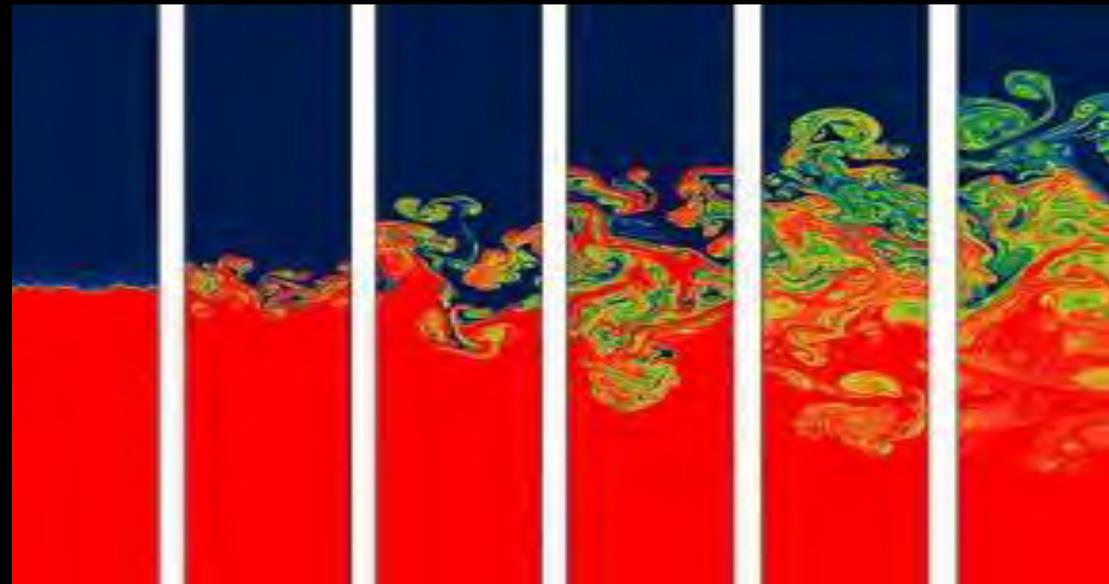
GPS Nav

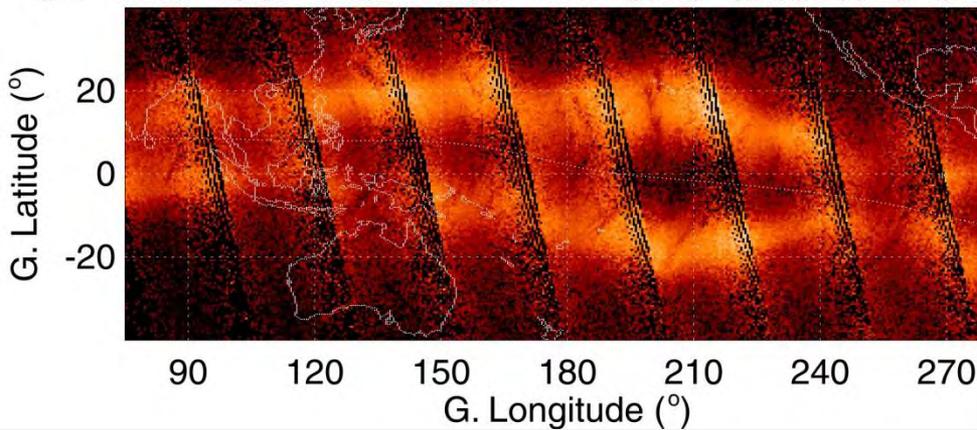
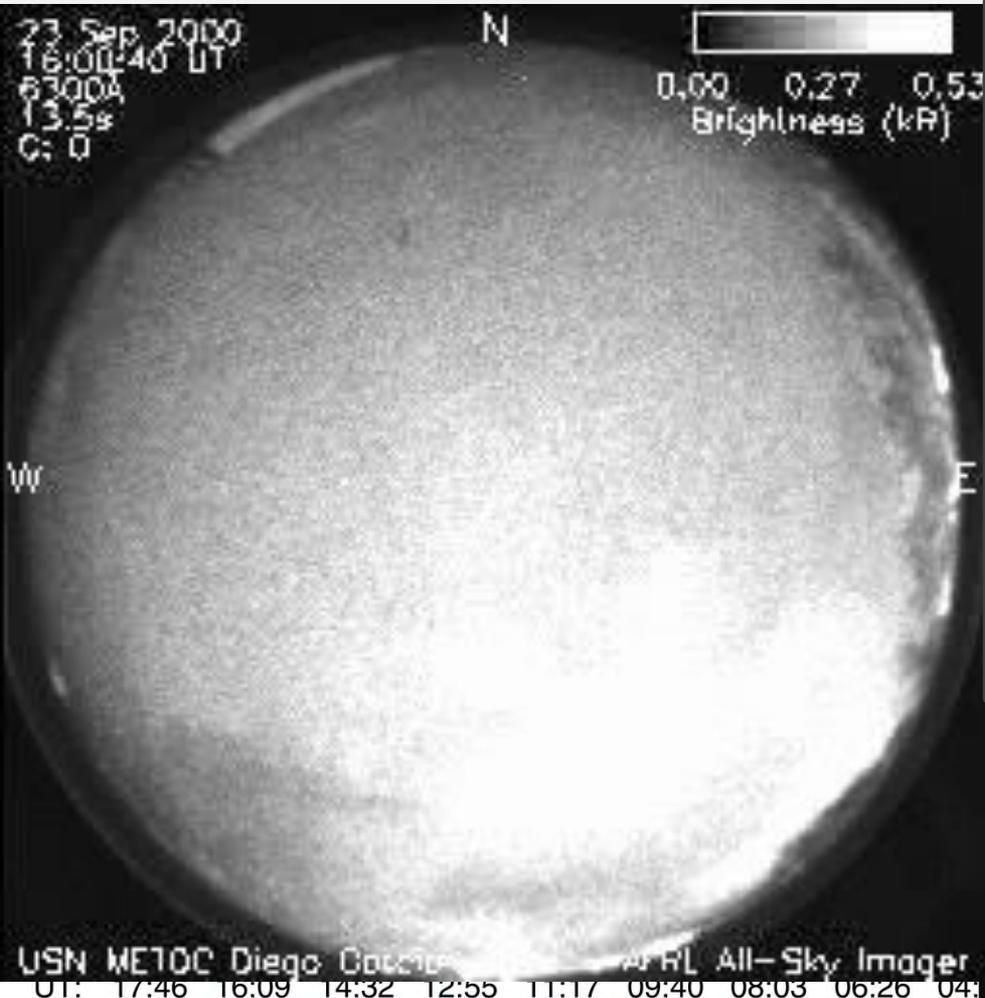
Clear

Scintillated/Lost Data

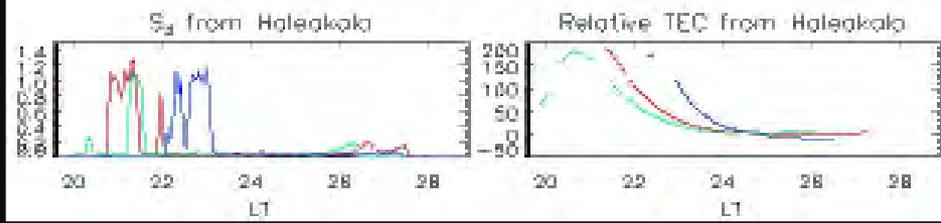


Scintillation: Rayleigh-Taylor Instability in the Ionosphere





Haleakala Observations, Sep 29-30, 2002 19:37 LT

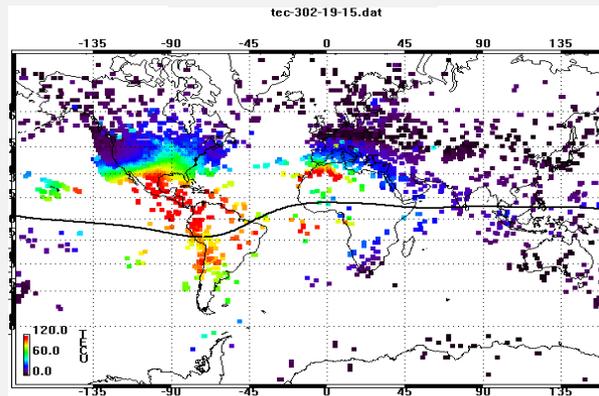


Storm-Enhanced Density (SED)

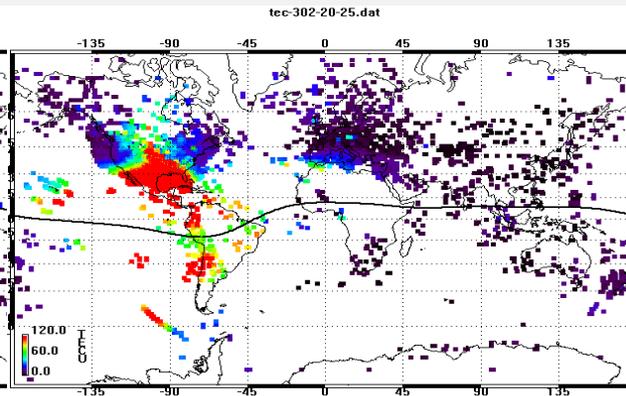
Oct 29, 2003 - “Halloween Storm”

- SED seen in total electron content (TEC) data collected by GPS
- This event impacted the WAAS system in the US for many hours

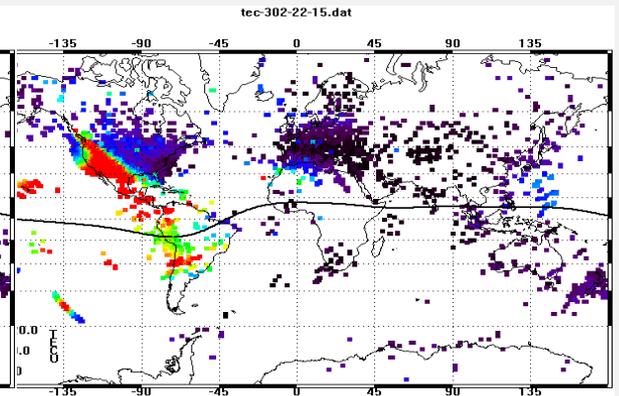
1915 UT



2025 UT



2215 UT



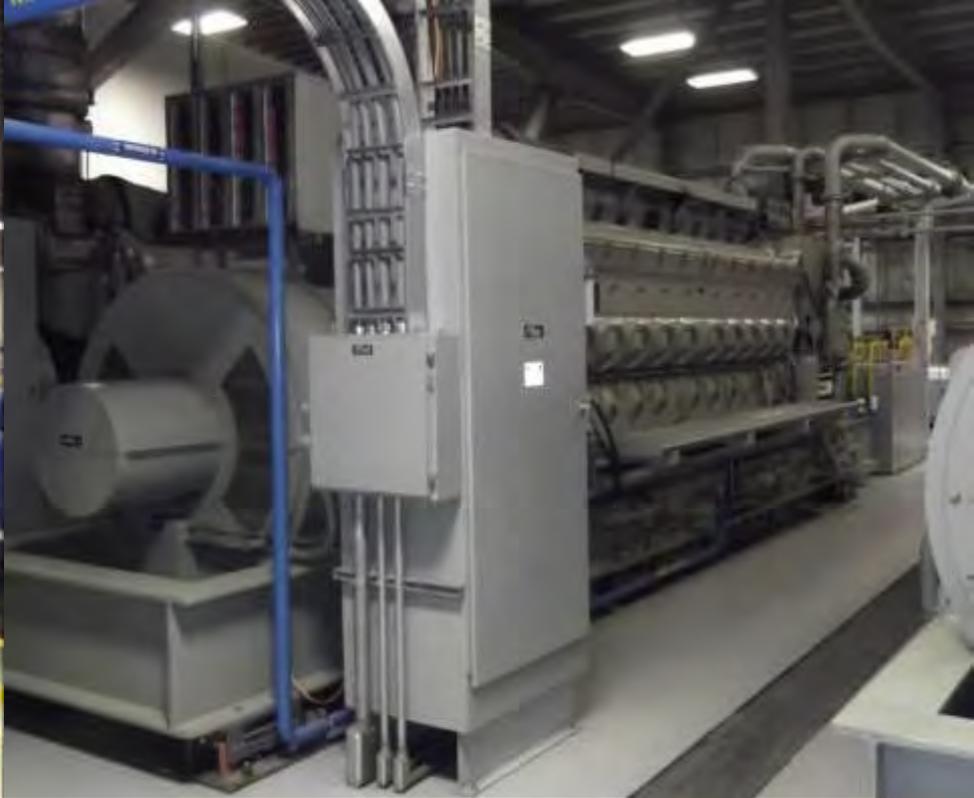
High Frequency Active Auroral Research Program (HAARP)



Transition to the GI 11 Aug 2015

8

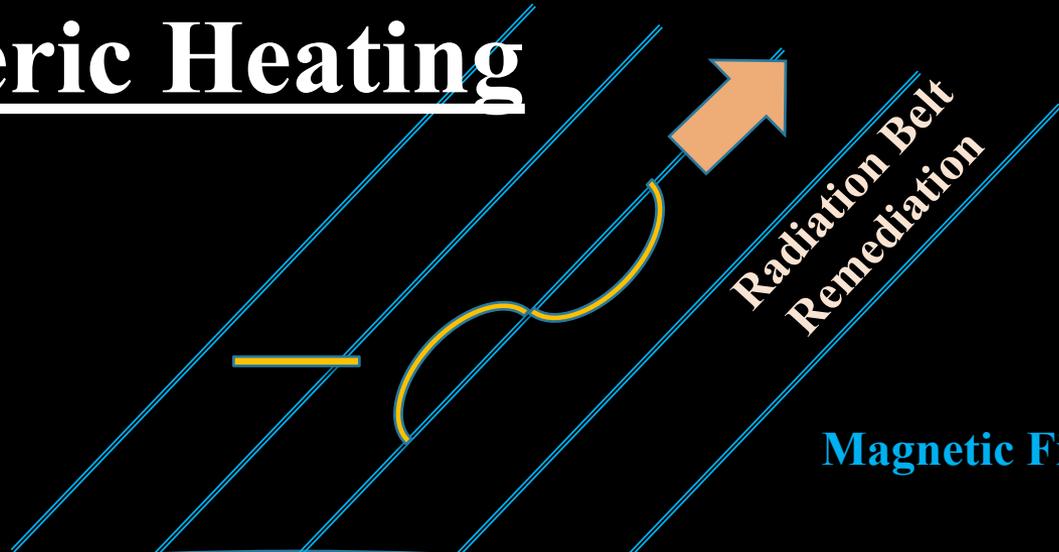
- 62.39 deg (North) lat; 145.15 deg (West) Gakona, AK
- Phased array HF transmitter; 2.8 to 10 MHz; 33 acres; 5 x 3600 hp diesel engines; 3.6 MW; \$290M



HF Ionospheric Heating



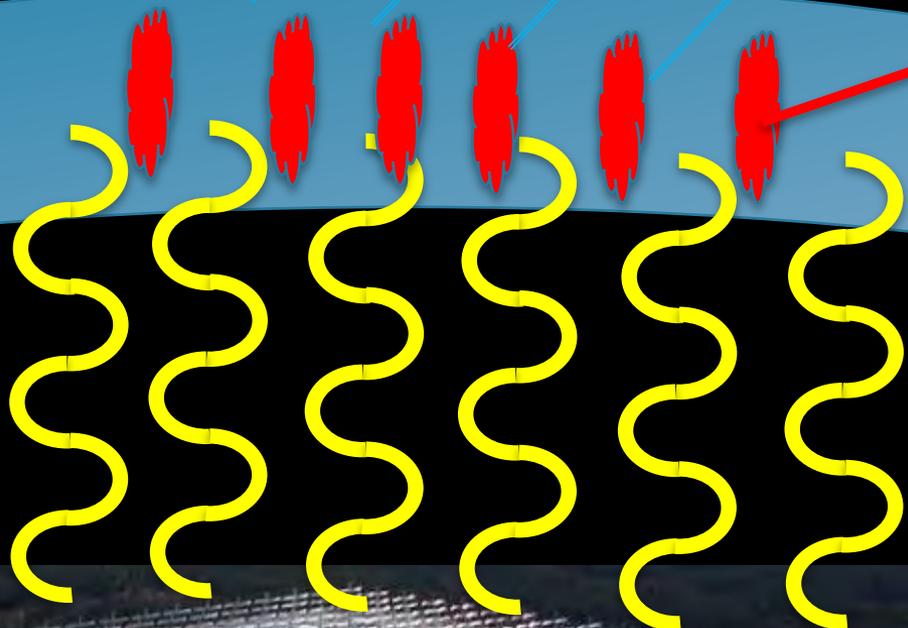
ELF, VLF



Ionosphere
90 – 2000 km

Ionospheric Irregularities

HF Energy
2.8 – 10 MHz
3.6 MW

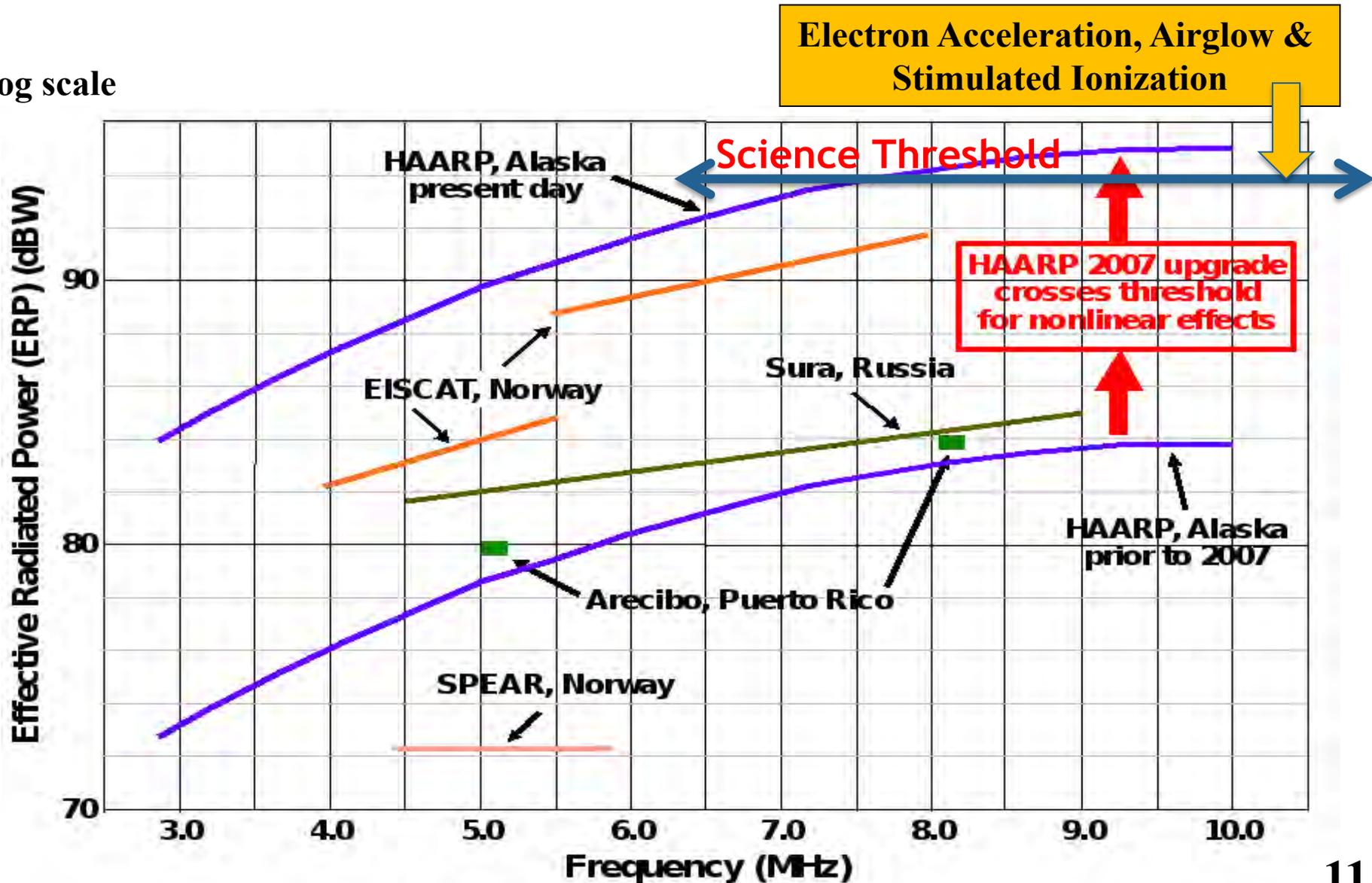


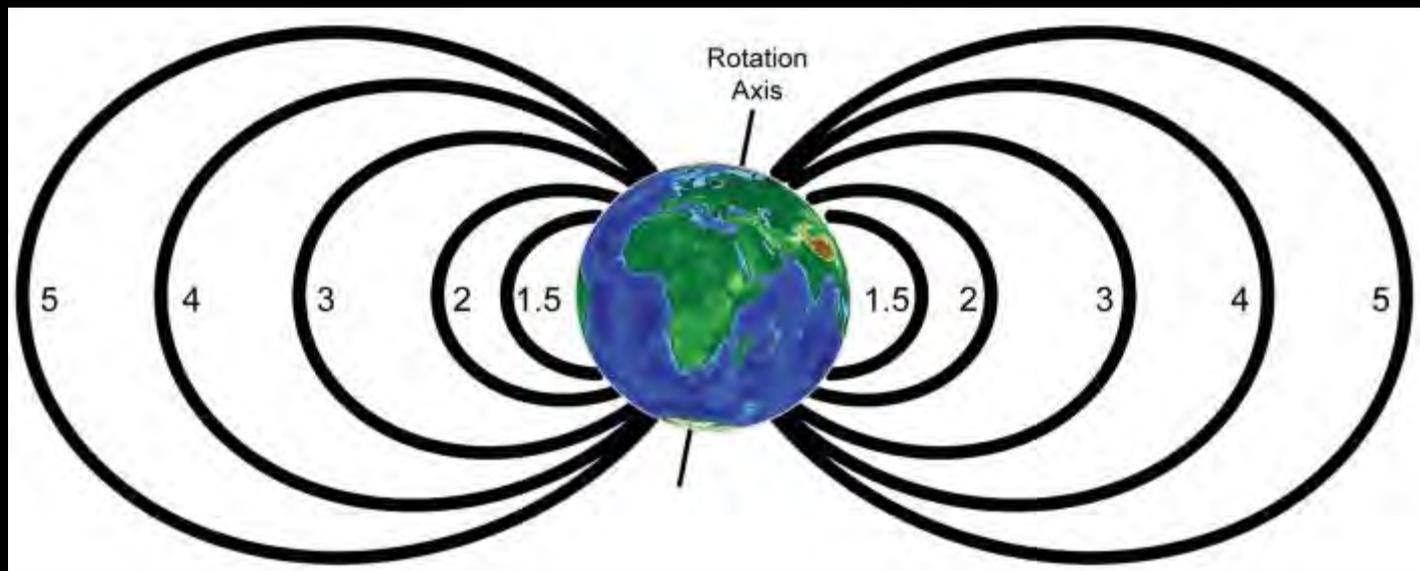
Submarine Communication



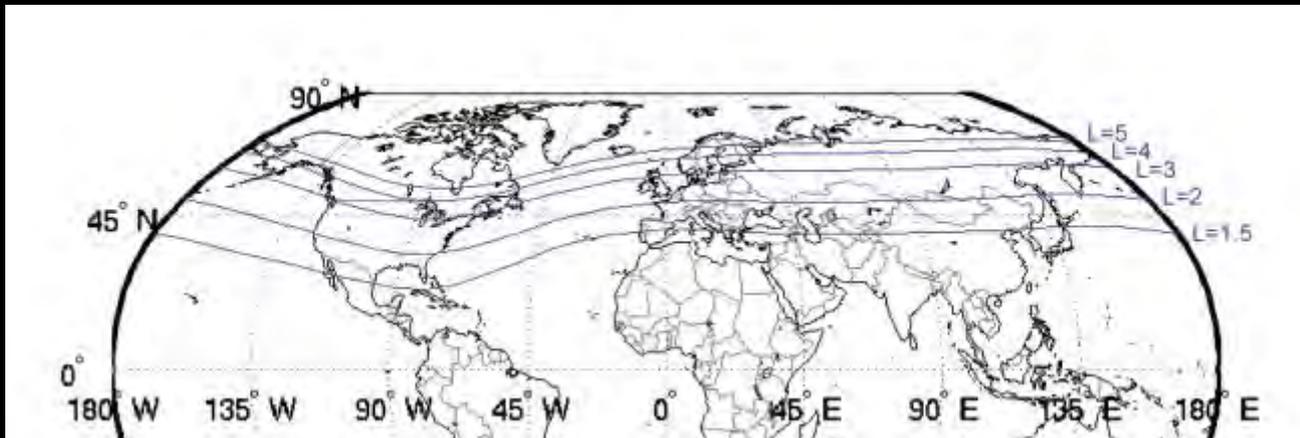
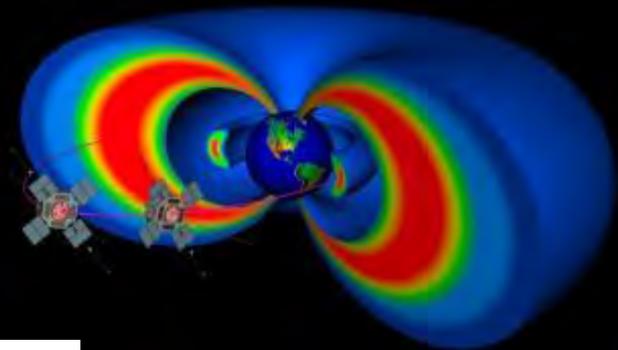
HAARP Compared to EISCAT, Sura & Arecibo

Log scale

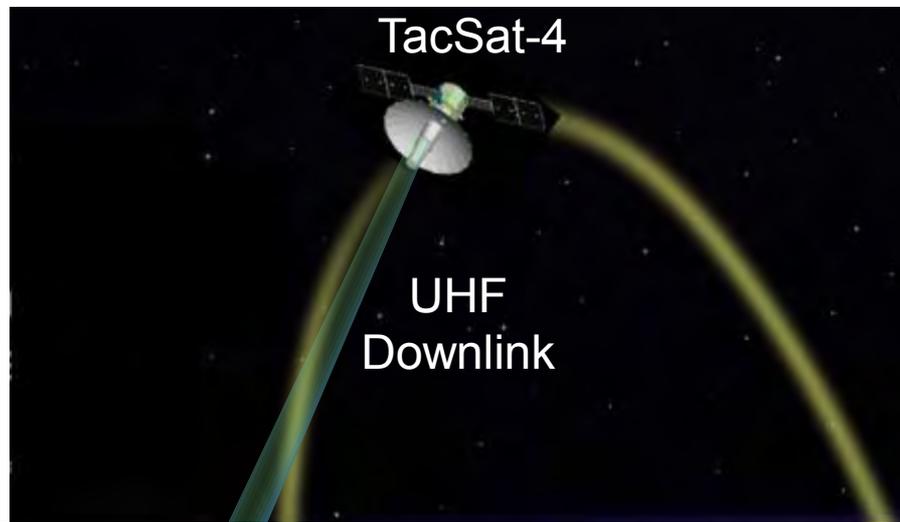




Van Allen Radiation Belts
L-Shells
NASA Van Allen Probes



COMMX Working with HAARP

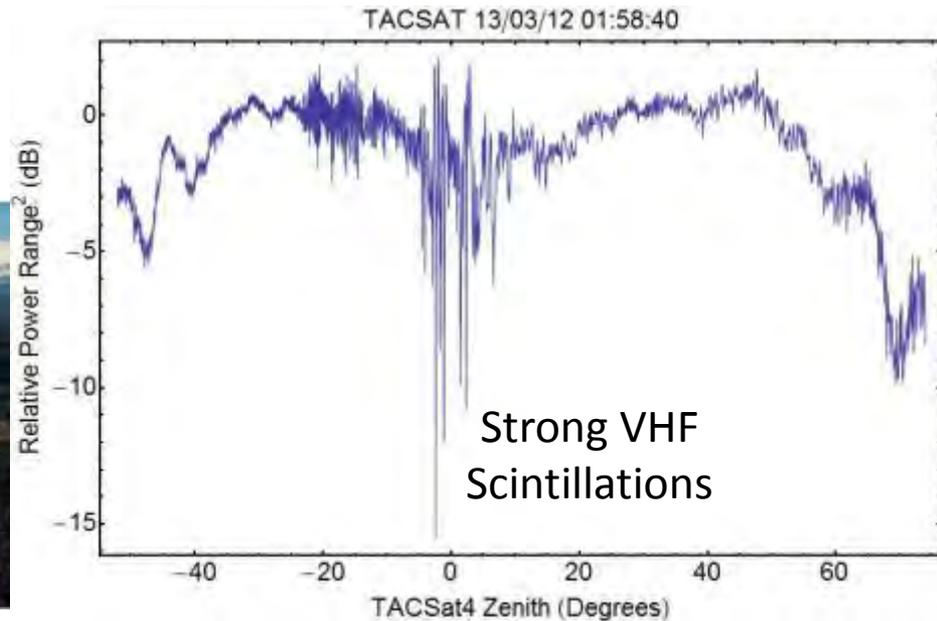


TACSat4
Actively
Pointed to
Ground
Receiver

Modified
Region

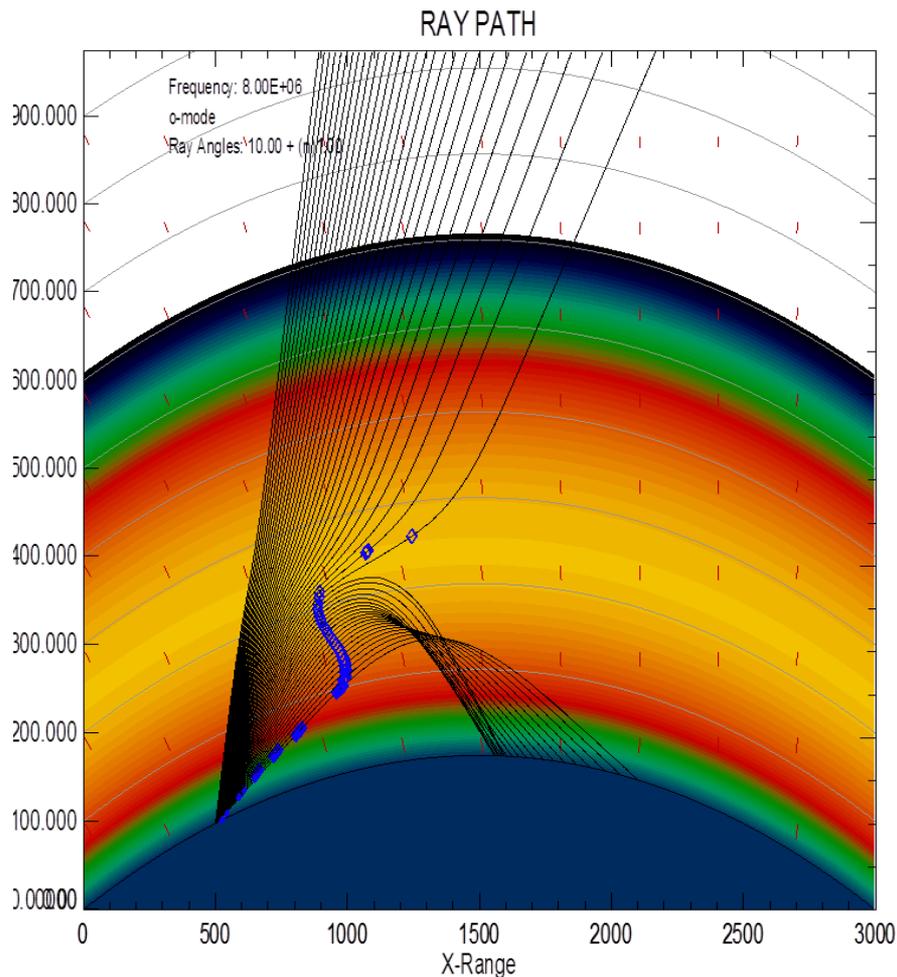
F-Layer Ionosphere

Courtesy Paul Bernhardt
NRL

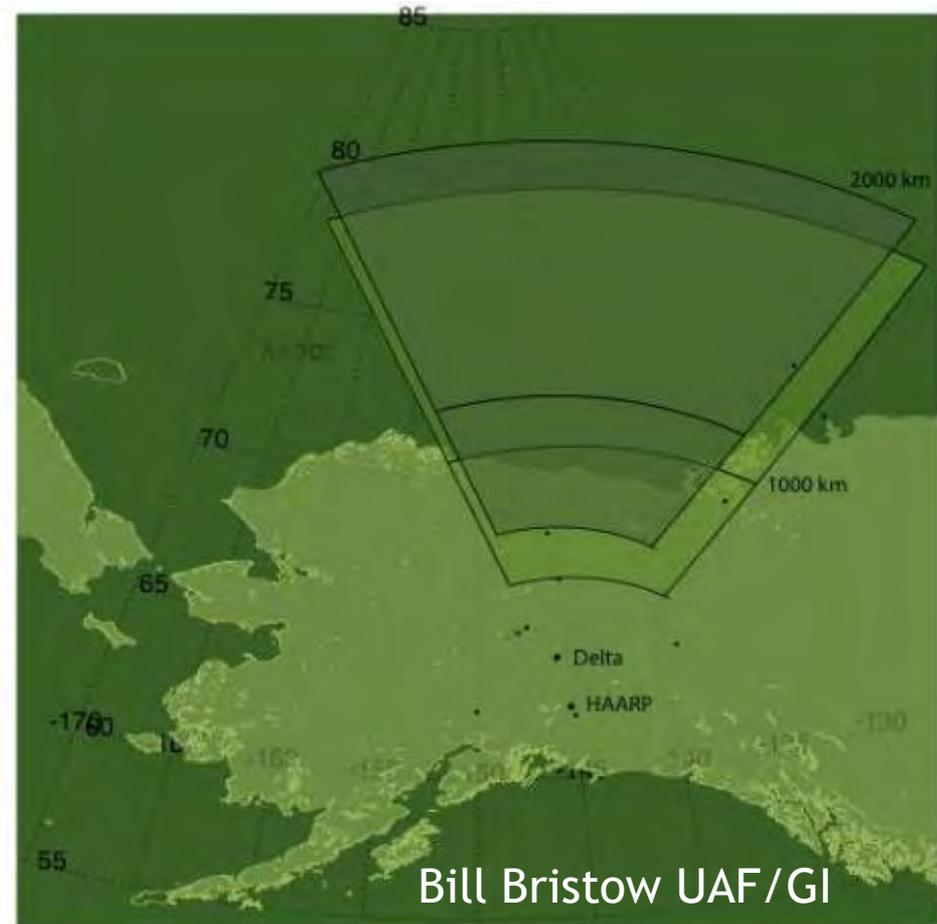


Over the Horizon Radar Experiments

8 MHz; Covers range of ~1100 km to ~1800 km from radar

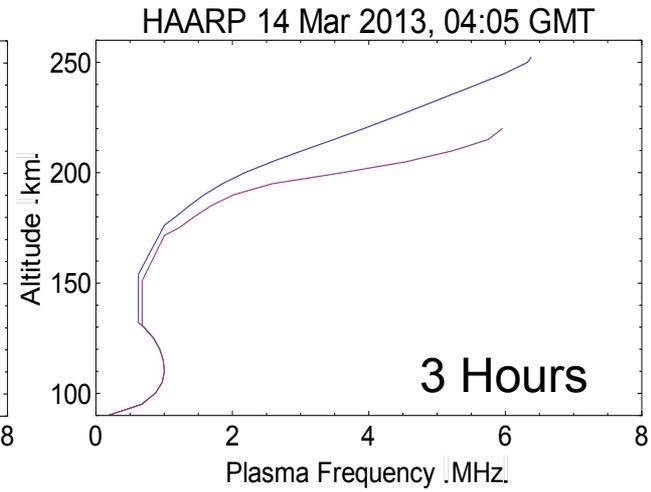
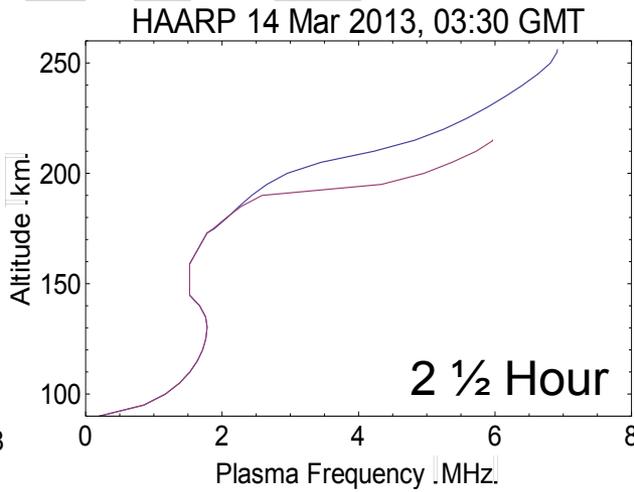
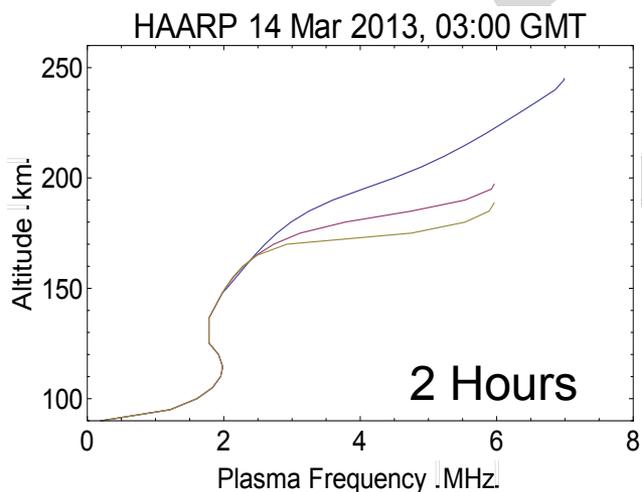
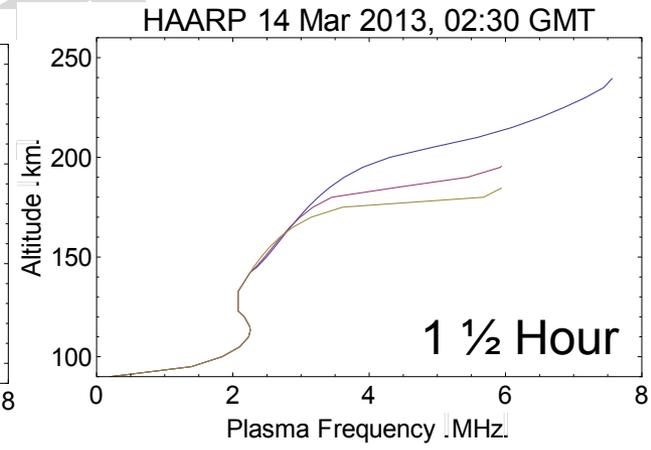
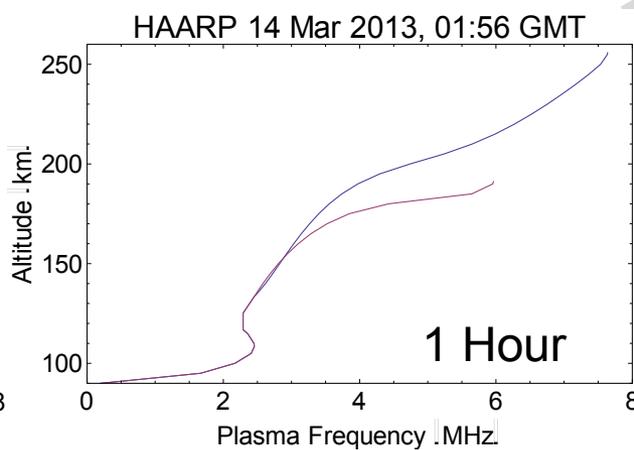
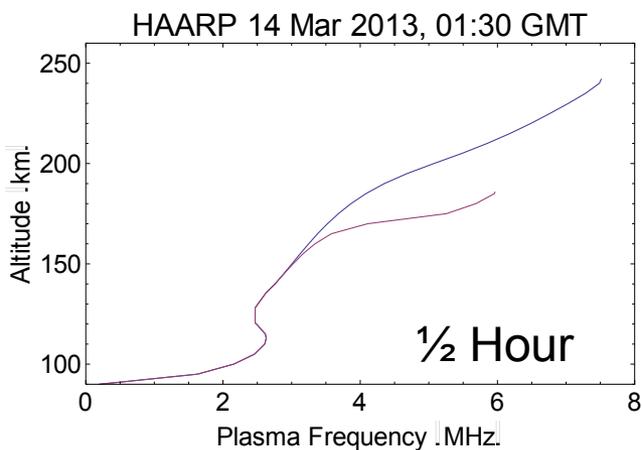
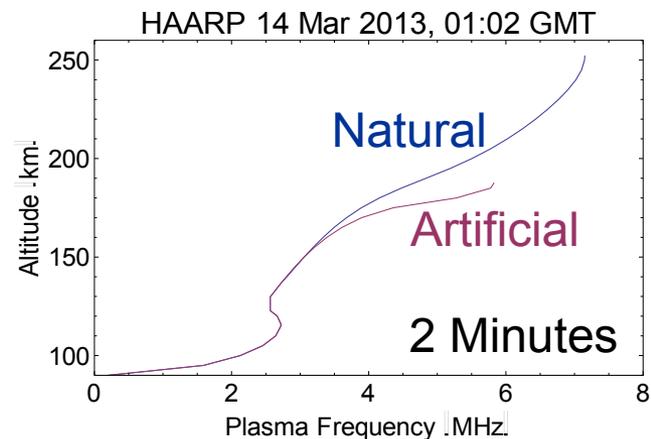


Offset of transmitter and receiver location; 2000 km range translates to about 80° latitude



14 March 2013 01:30 to 04:00 GMT Extended Artificial Ionization with 5.8 MHz Twisted Beam

Courtesy Paul Bernhardt
NRL



2013: Two National Research Council Studies Involving HAARP

- **2013 Decadal Survey in Solar and Space Physics**

- Priority - Fully realize the potential of ionospheric modification techniques through collocation of modern heating facilities with a full complement of diagnostic instruments including incoherent scatter radars. This effort requires coordination between NSF and DOD agencies in planning and operation of existing and future ionospheric modification facilities.



- **Mar 2013 - Workshop: Opportunities for High-Power, High-Frequency Transmitters to Advance Ionospheric/Thermospheric Research**

- NRC Workshops do not provide recommendations but report contains 72 pages of HAARP science
- Themes: Geospace and space weather; Stimulated emission and radiation belts; radio science, communications, and radar
- Strong recommendation to co-locate incoherent scatter radar



**Thank
You**

