The Largest Ionospheric Disturbances Produced by the HAARP HF Facility

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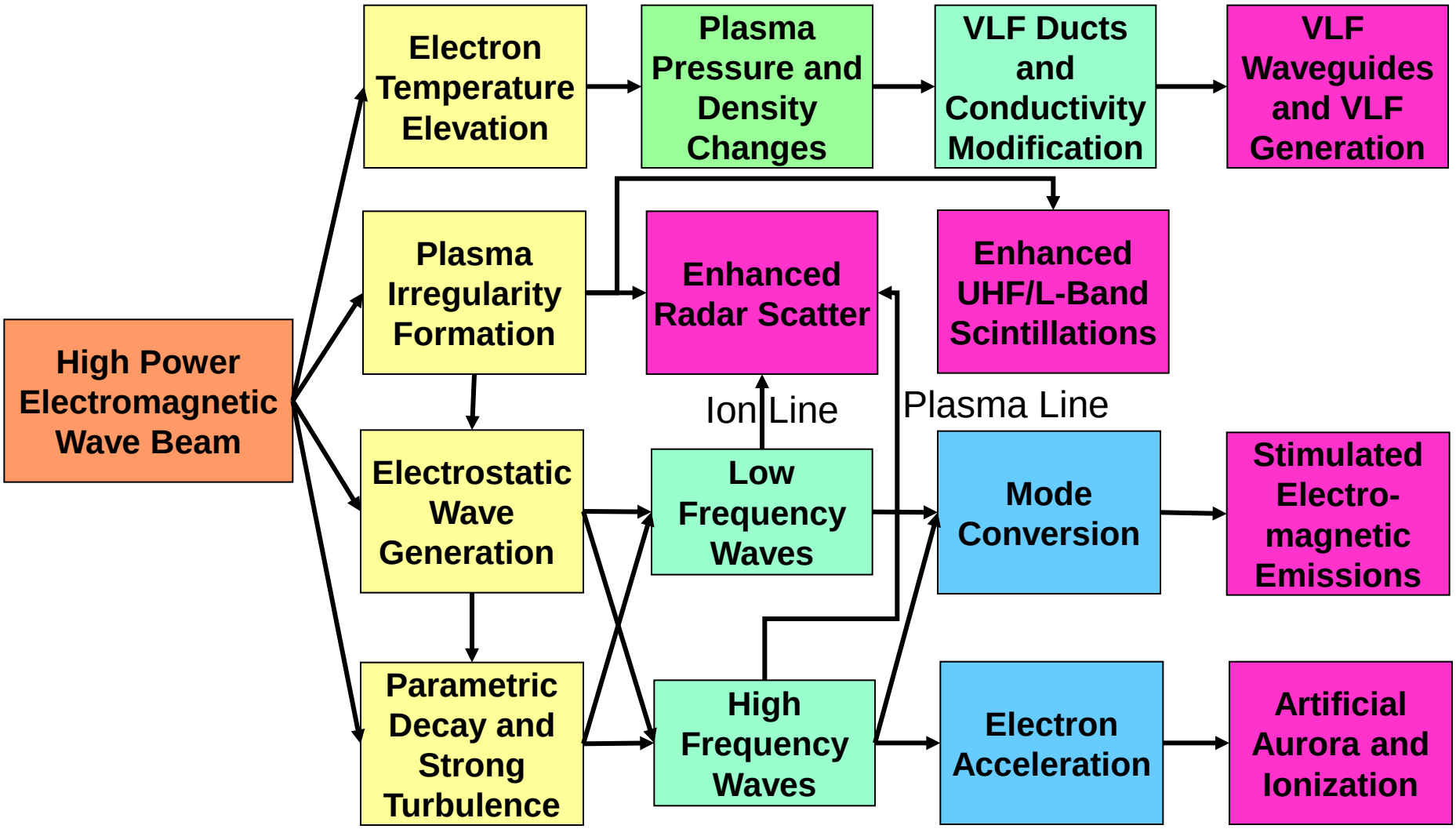
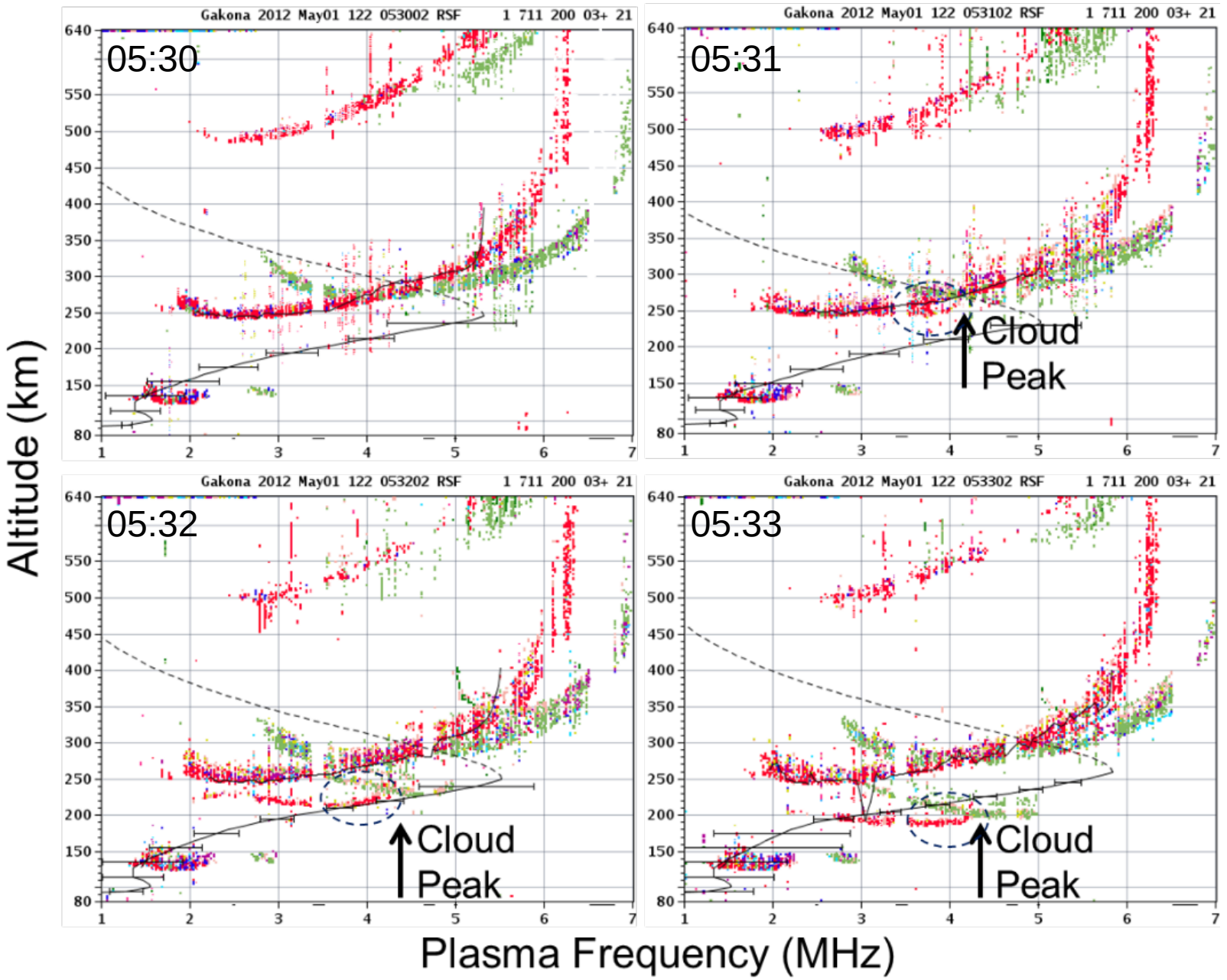
HAARP Disturbances

- Ionospheric Modification Physics
- Artificial Ionization
  - Associated Stimulated Electromagnetic Emissions
  - Largest Artificial Density Below Natural Ionosphere
  - Use of Twisted Beam to Form Stable Ionization
  - Longest Duration Plasma Cloud
- VHF/UHF Scintillations
  - Historical Results
  - Strongest SATCOM Scintillations
  - Role of Artificial Ionization
- Implications of Artificial Disturbances

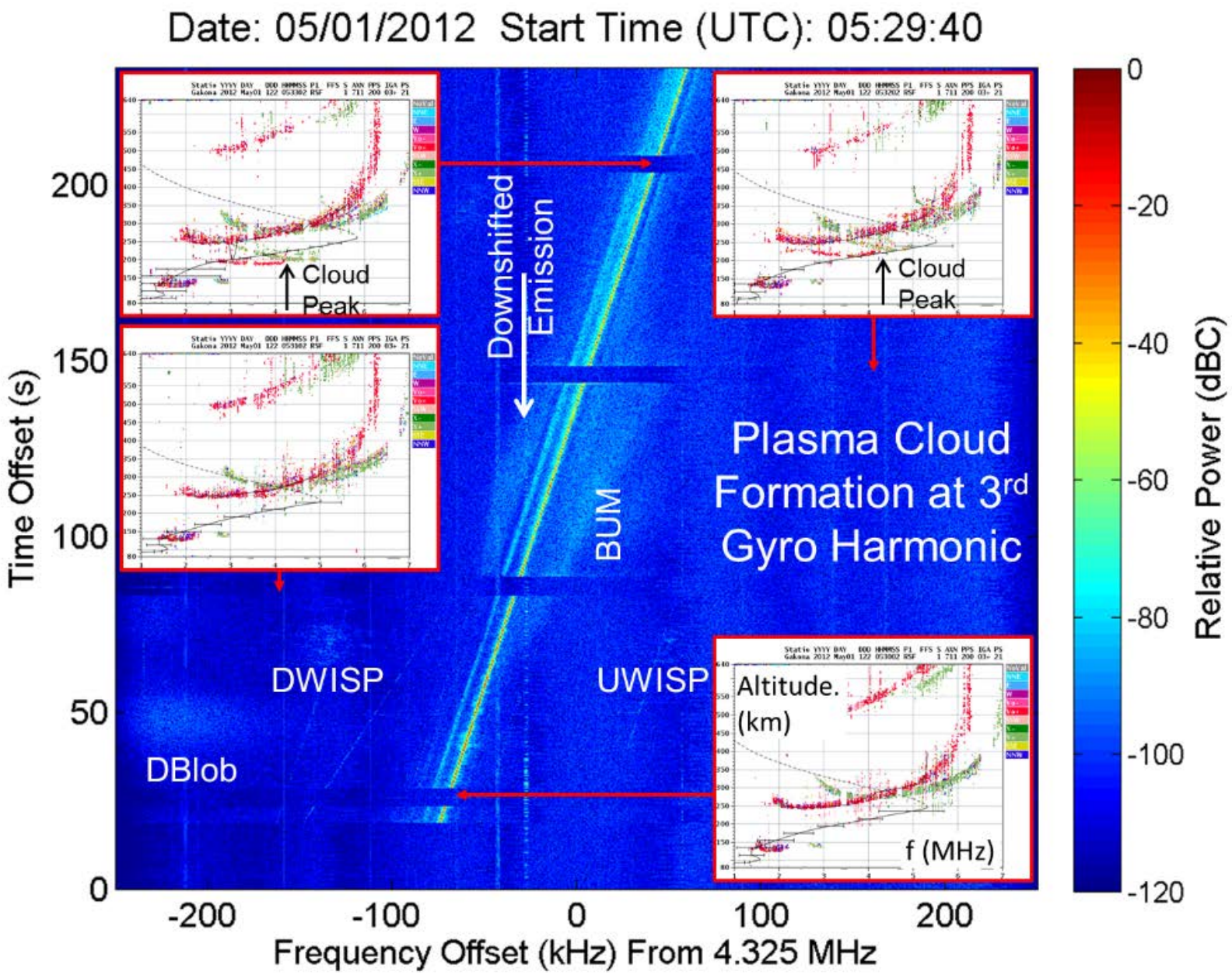
Ionospheric Modification with High Power Radio Waves



Artificial Ionization Cloud Formed Around 4.325 MHz

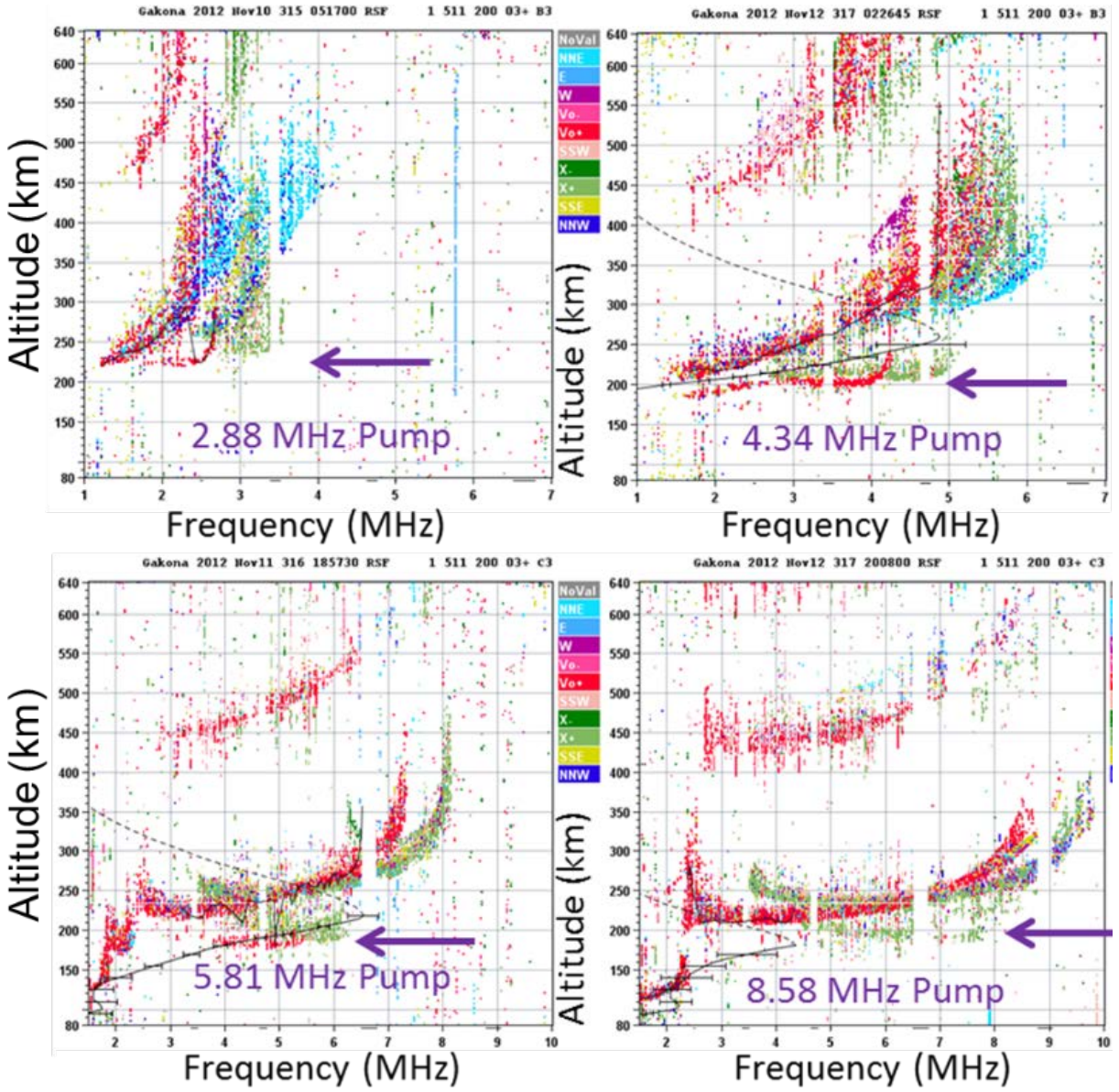


SEE and AI Observed during 3rd f_{ce} Frequency Sweep

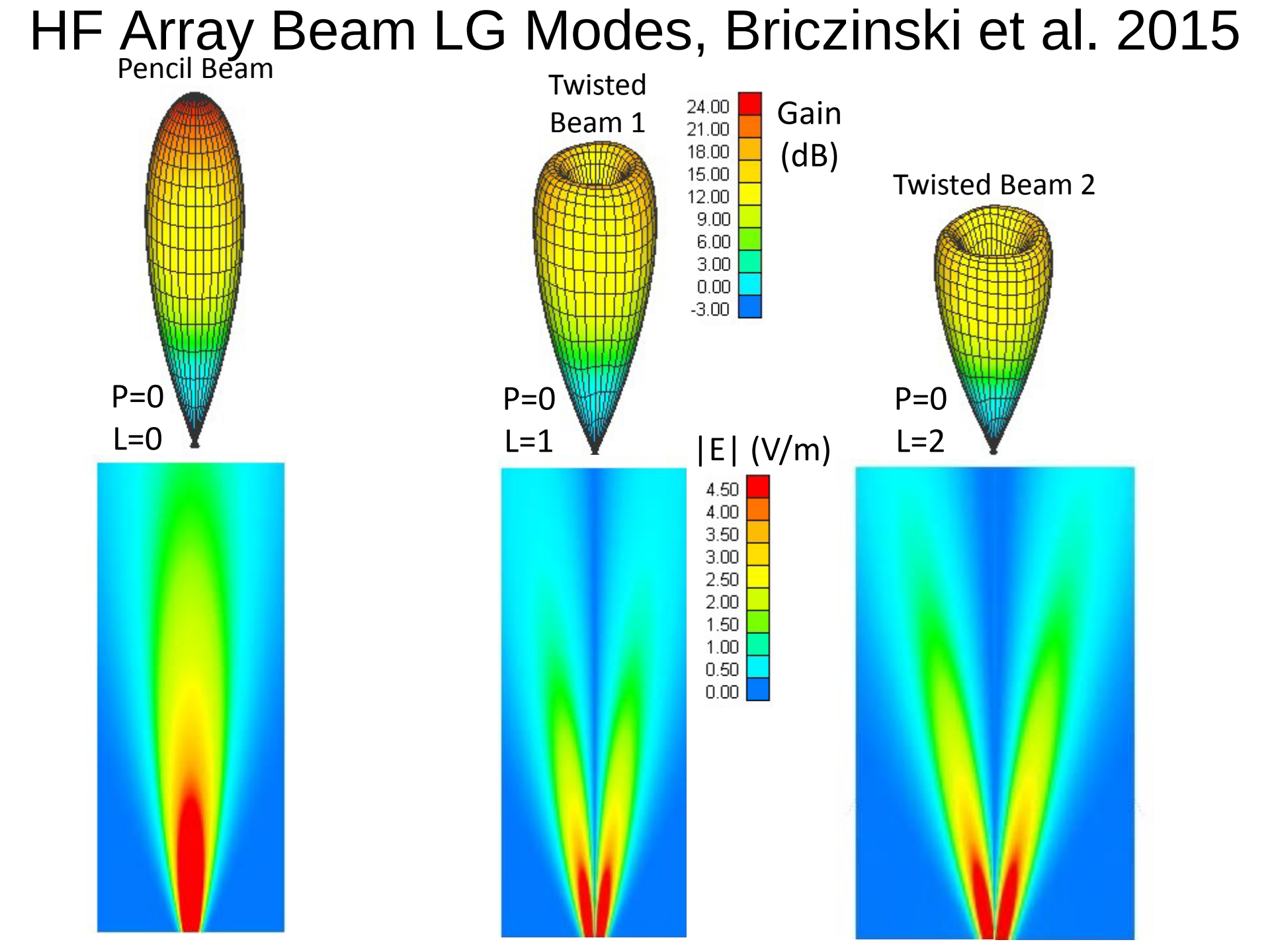


2nd, 3rd, 4th, and 6th Harmonic Artificial Plasma Clouds

Near Multiples of 1.44 MHz Electron Gyro Frequency

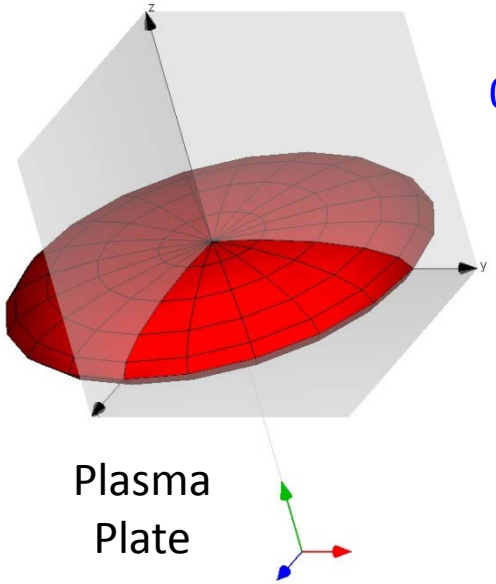


HF Array Beam LG Modes, Briczinski et al. 2015

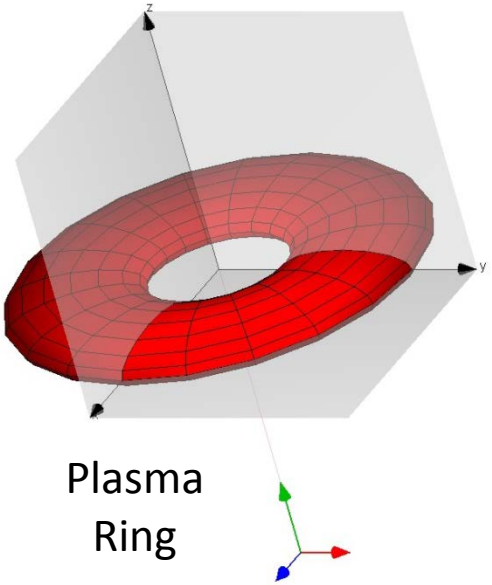


Simulations of Plane EM Wave Interactions with Plasma Plate and Ring

3 MHz Pump
0.9 km Diameter Cloud

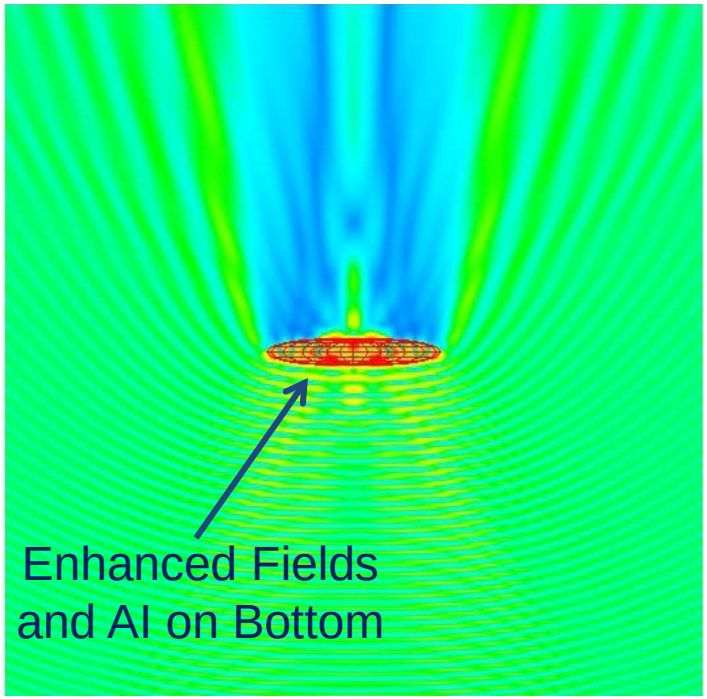


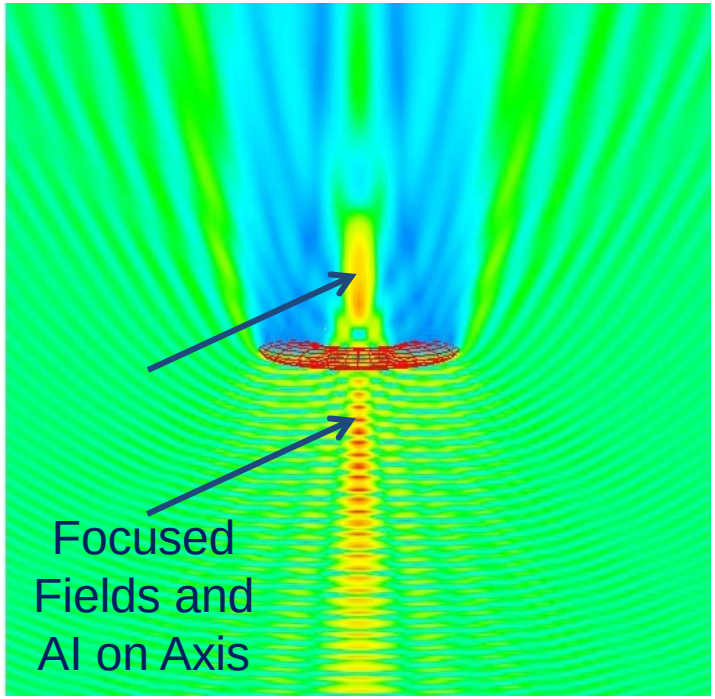
Plasma
Plate



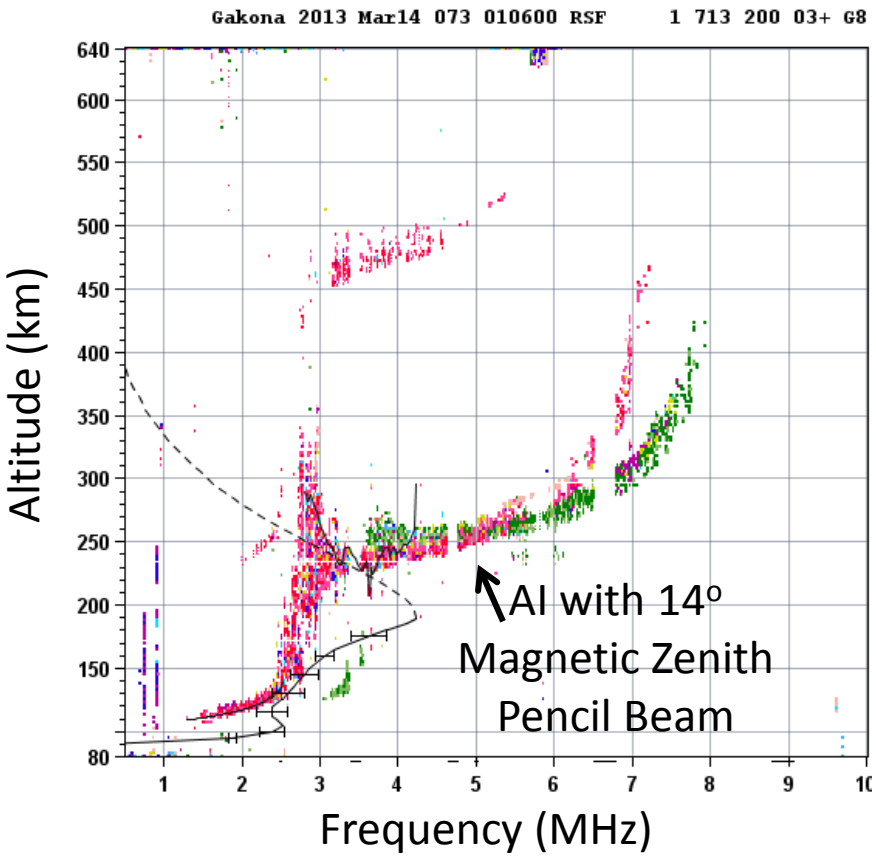
Plasma
Ring

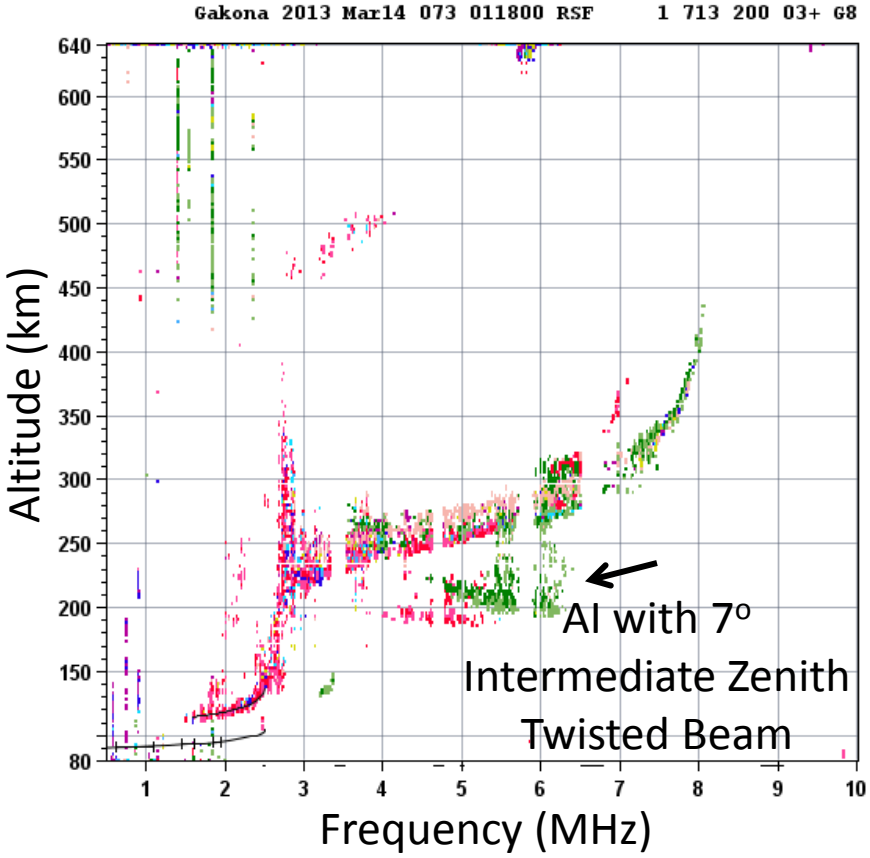
|E| (V/m)



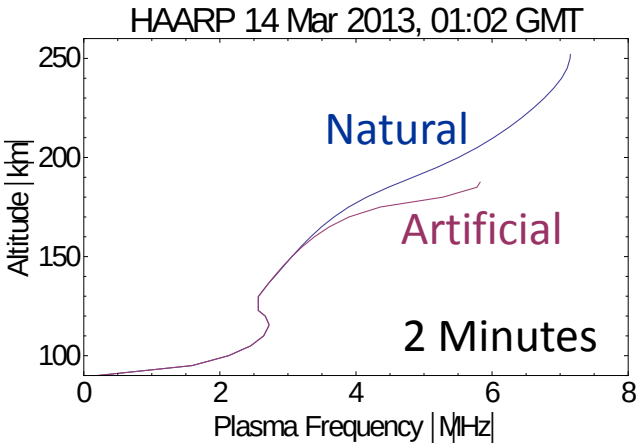


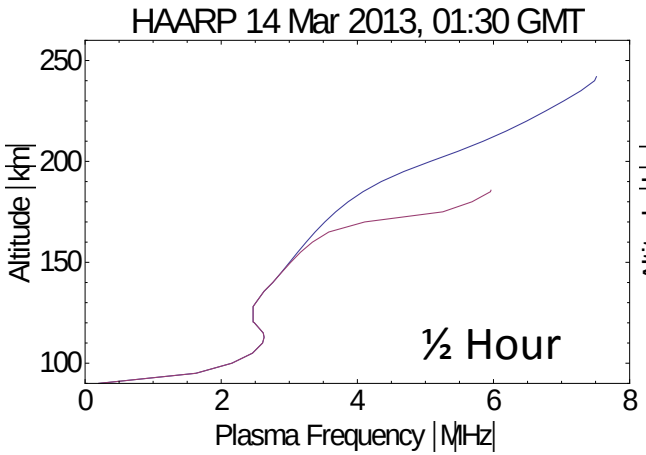
14 March 2013 01:00 to 01:20 GMT
Extended Artificial Ionization with 5.8 MHz Twisted Beam

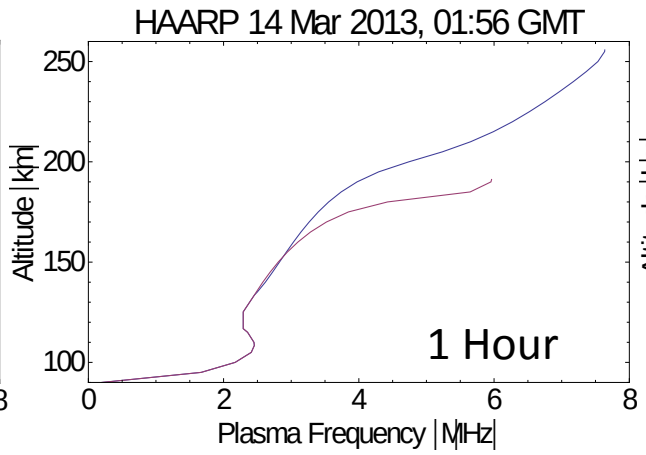


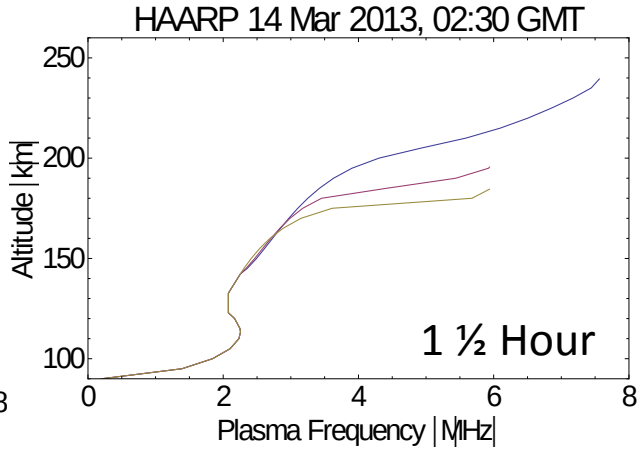


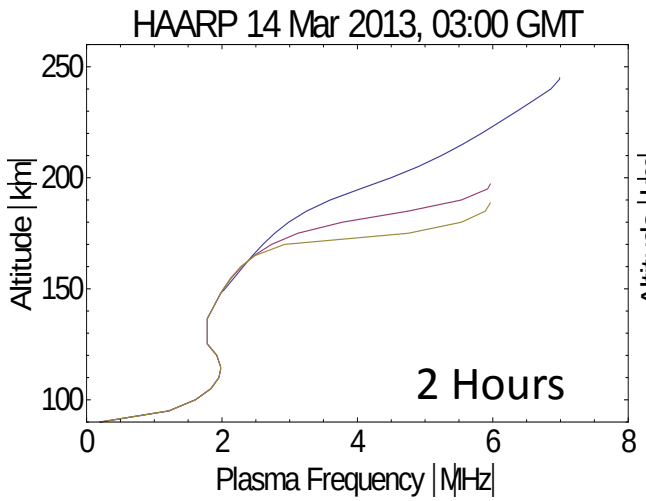
14 March 2013 01:30 to 04:00 GMT
Extended Artificial Ionization
with 5.8 MHz Twisted Beam

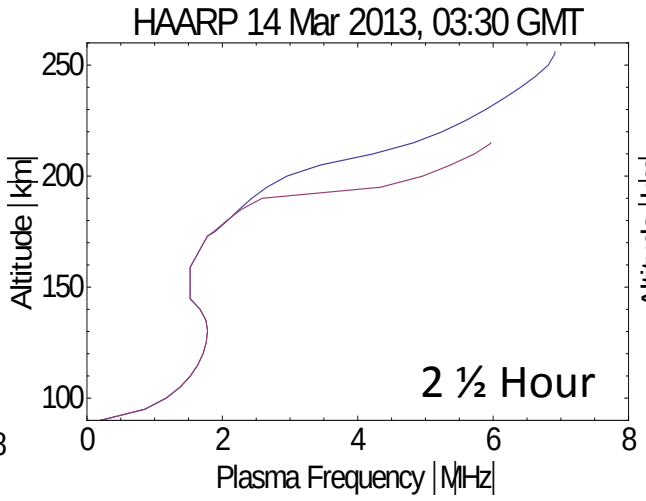


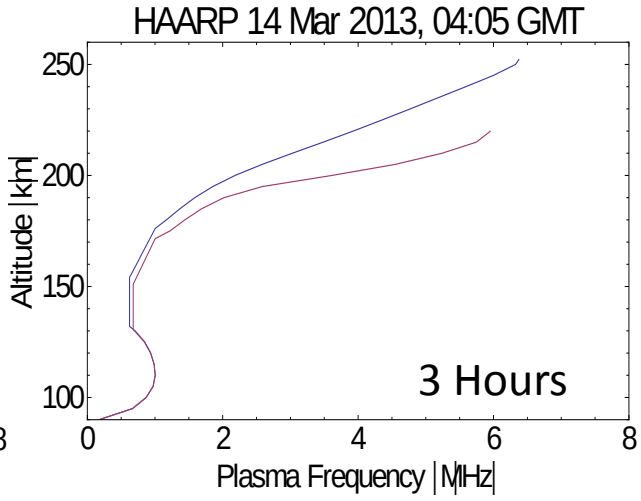












Underwhelming UHF Scintillations Produced by EISCAT Heating in Norway

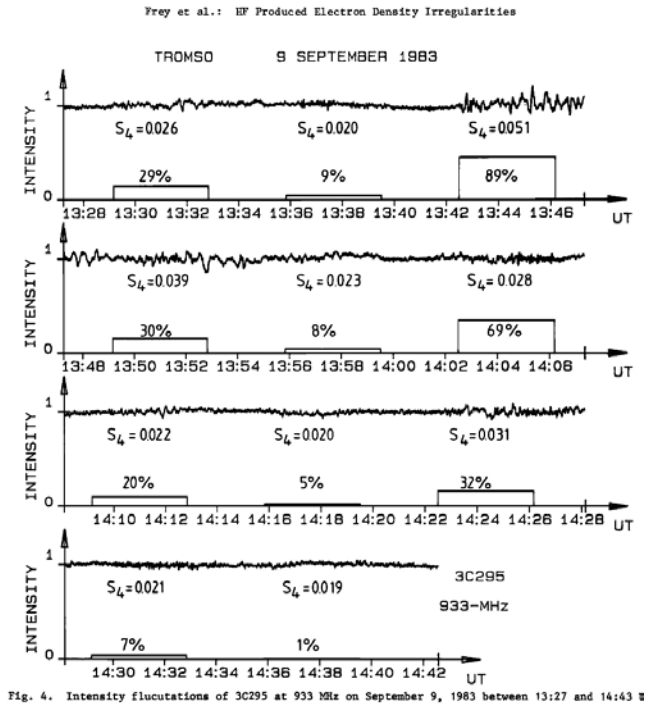


Fig. 4. Intensity flucutations of 3C295 at 933 MHz on September 9, 1983 between 13:27 and 14:43 U

BASU ET AL.: SCINTILLATIONS INDUCED BY HF WAVES AT TROMSØ

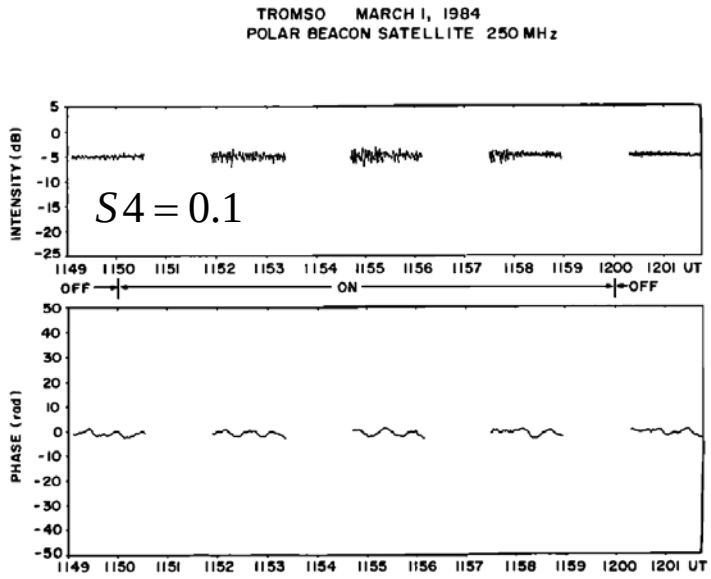


Fig. 2. The development of (top) intensity and (bottom) phase scintillations of 250-MHz transmissions when the HF heater was turned on. The data segments were acquired over 82 s at intervals of 168 s.

BASU ET AL.: EVOLUTION OF IRREGULARITIES CAUSED BY HF WAVES

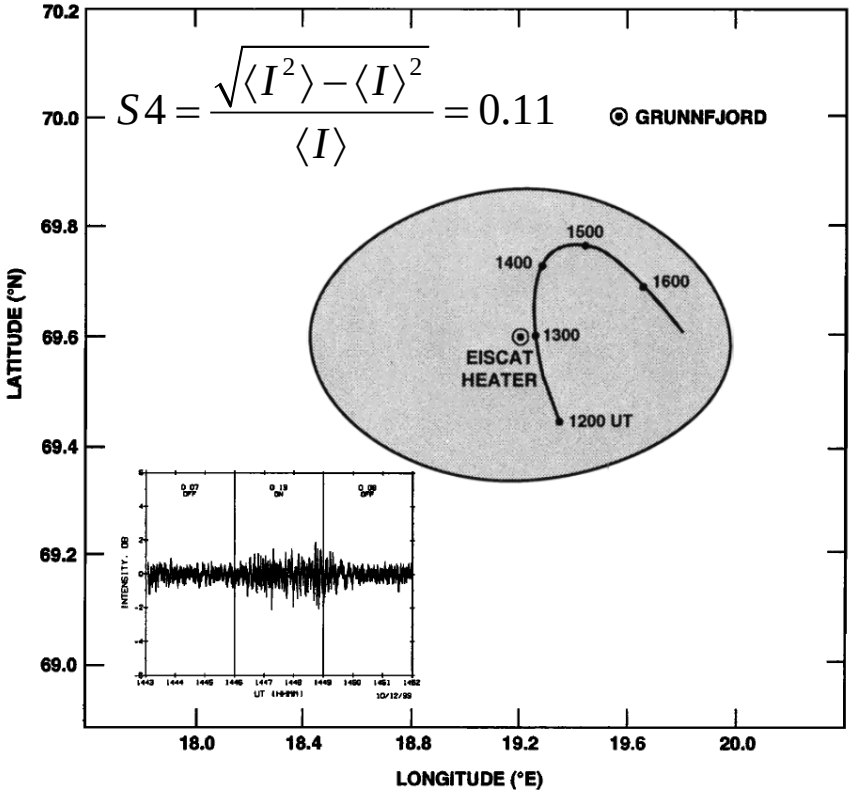
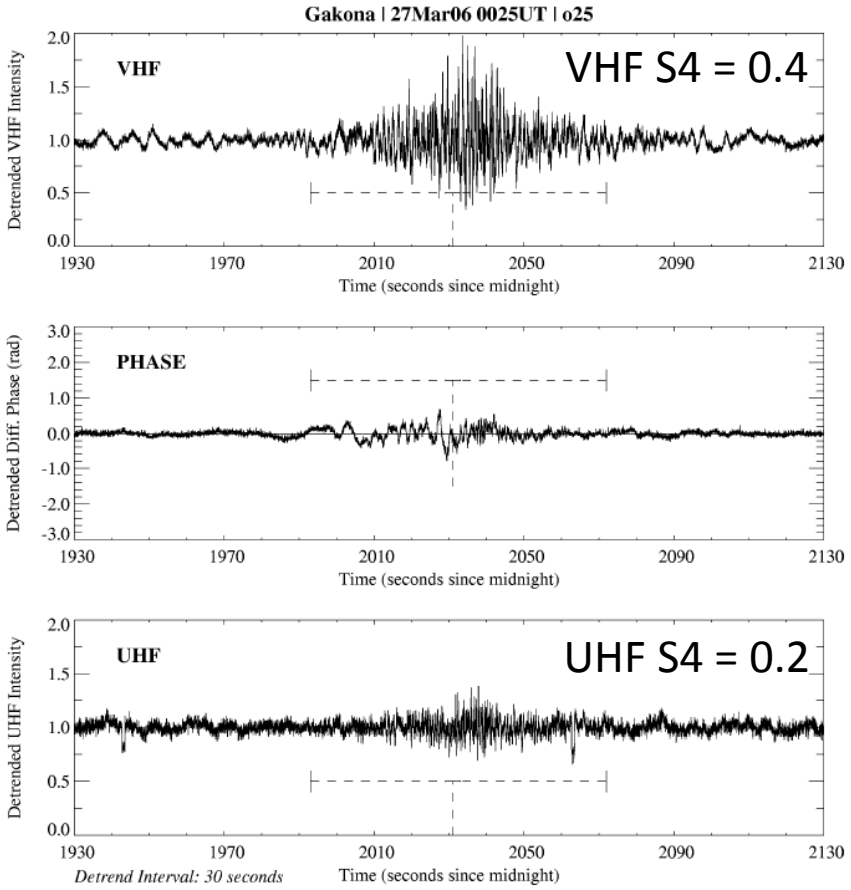


Figure 1. Illustrates the geometry of the observations using the EISCAT heater. The shaded region indicates the half power beam circle of the heater along with the locus of the intersection of the propagation path from the polar beacon satellite to the receiver at Grunnfjord with the HF reflection altitude of 250 km. The inset diagram shows the growth and decay of scintillations at 250 MHz during the heater "on" and "off" cycles.

Weak Scintillations at 150 and 400 MHz Produced by HAARP Heating in Alaska

Secan et al., AFRL Report AFRL-VS-HA-TR-2008-1139

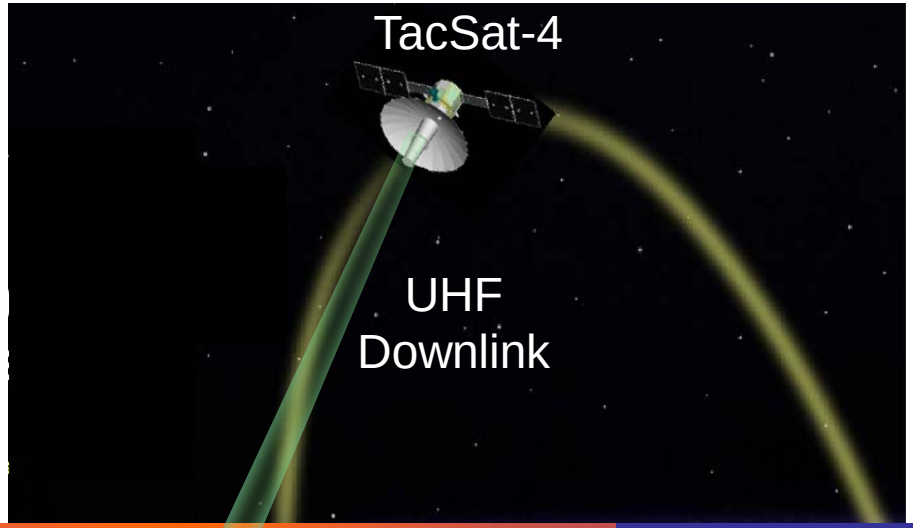


Detrended VHF (top panel), UHF (middle panel), and differential phase (lower panel) from a 200-second segment of data collected at Gakona, AK, from the Oscar 25 pass at 0033 UT on 27 March 2006. The vertical dashed line indicates the time of closest approach to the field-aligned point (as observed from Gakona), and the horizontal dashed lines indicate the time during which the ray path was within 8° of beam-center (the region within which heater-generated optical emissions are typically observed).

Amplitude Scintillation Index

$$S4 = \frac{\sqrt{\langle I^2 \rangle - \langle I \rangle^2}}{\langle I \rangle}$$

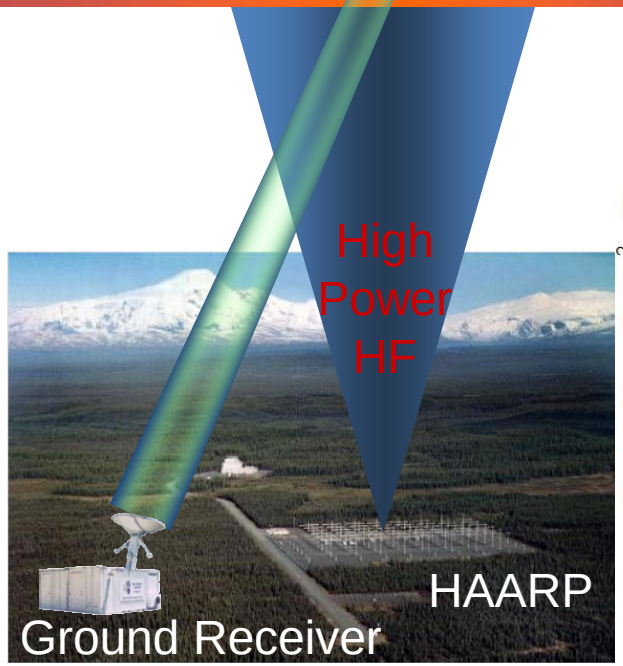
COMMX Working with HAARP

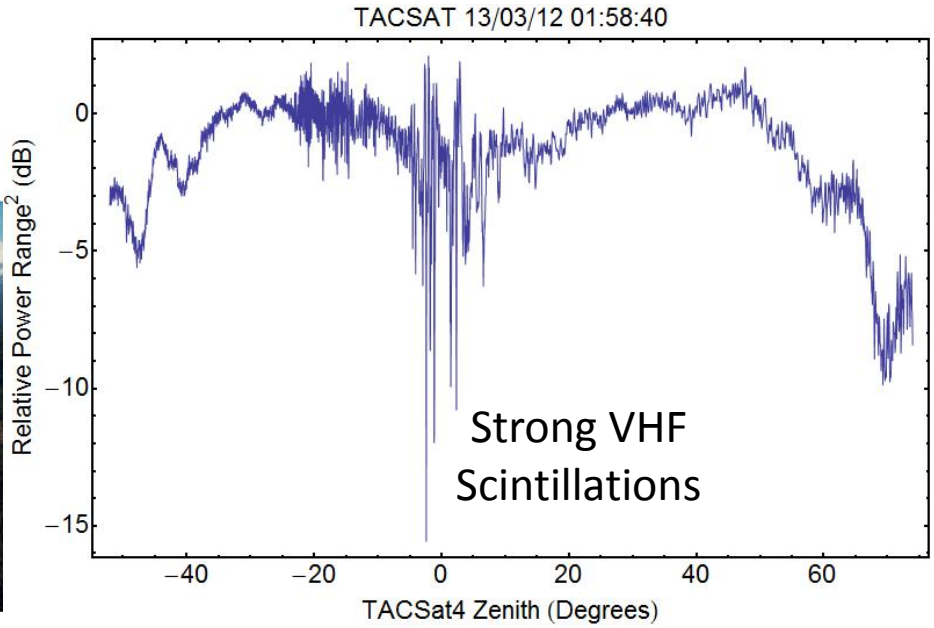


TACSat4 Actively Pointed to Ground Receiver

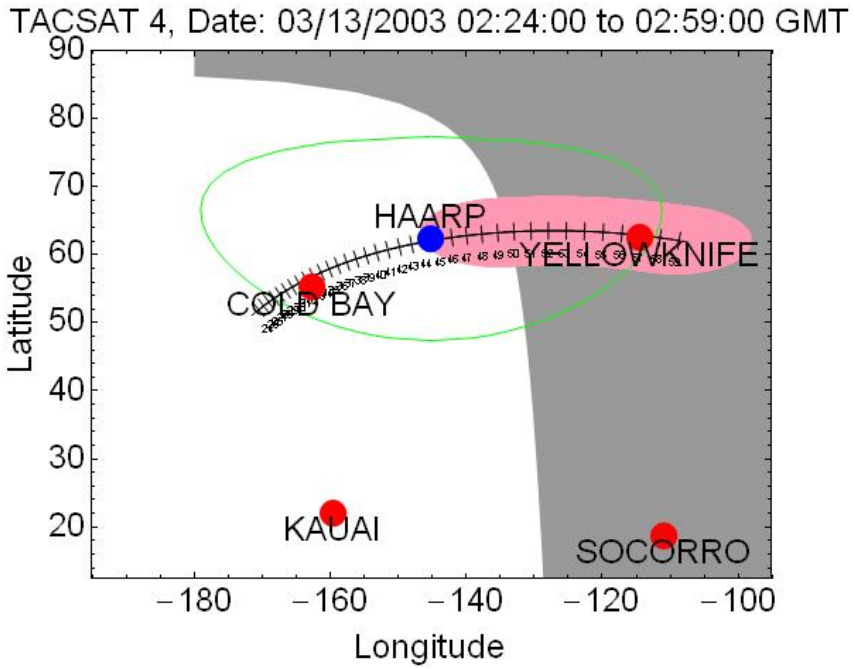
Modified Region

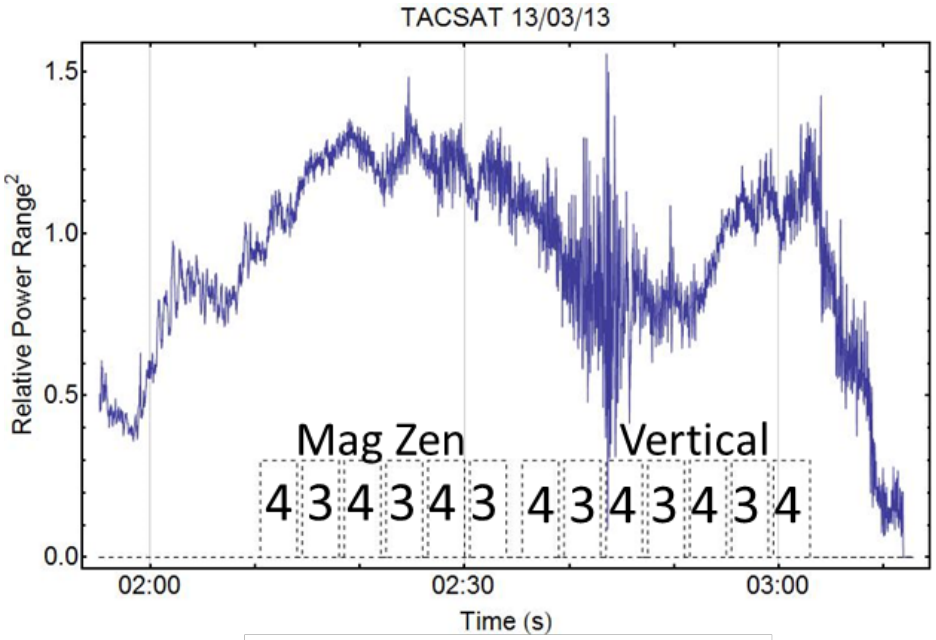
F-Layer Ionosphere

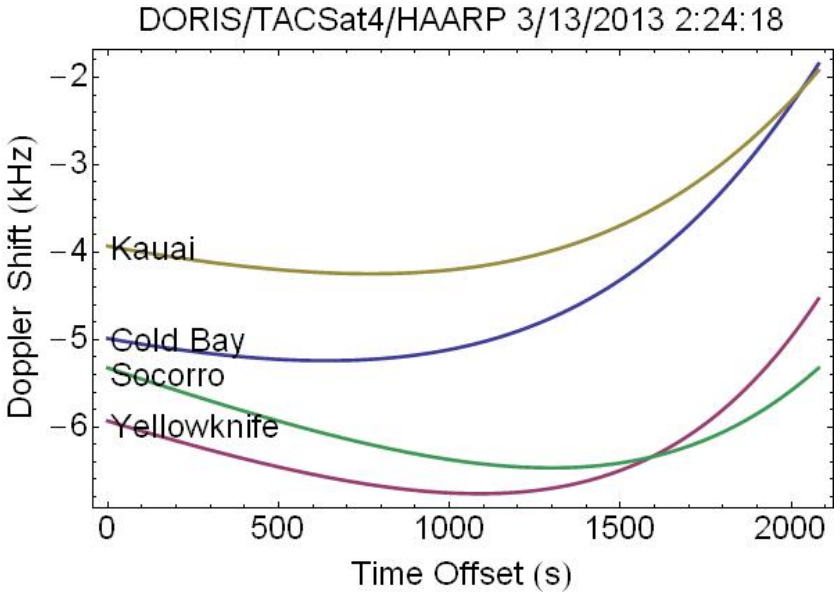


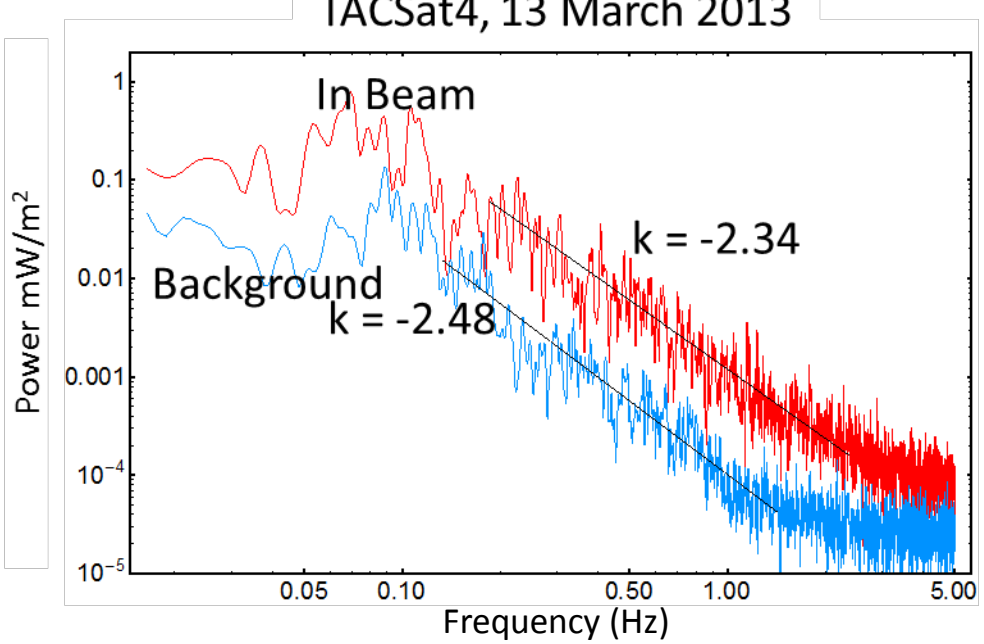


13 March 2013 TACSat4 COMMX Satellite Experiments

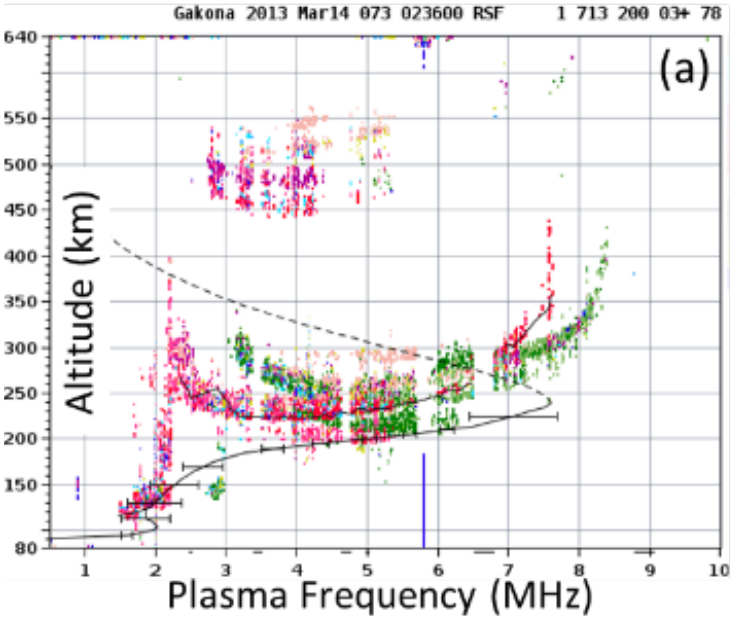


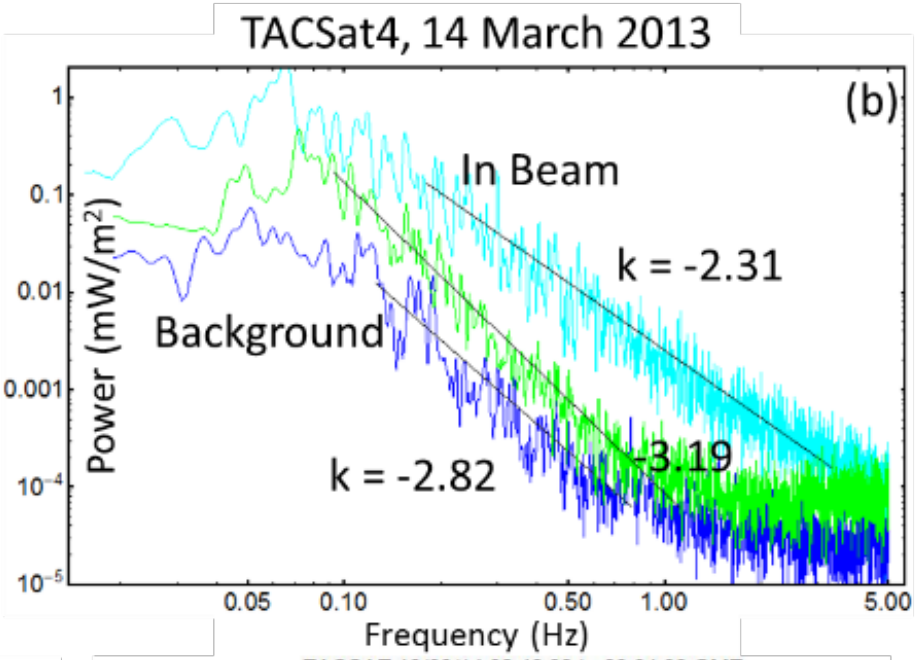


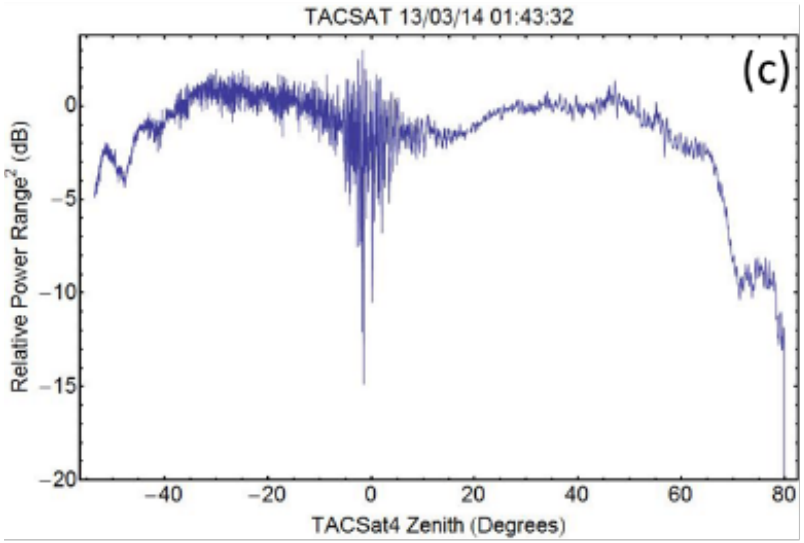


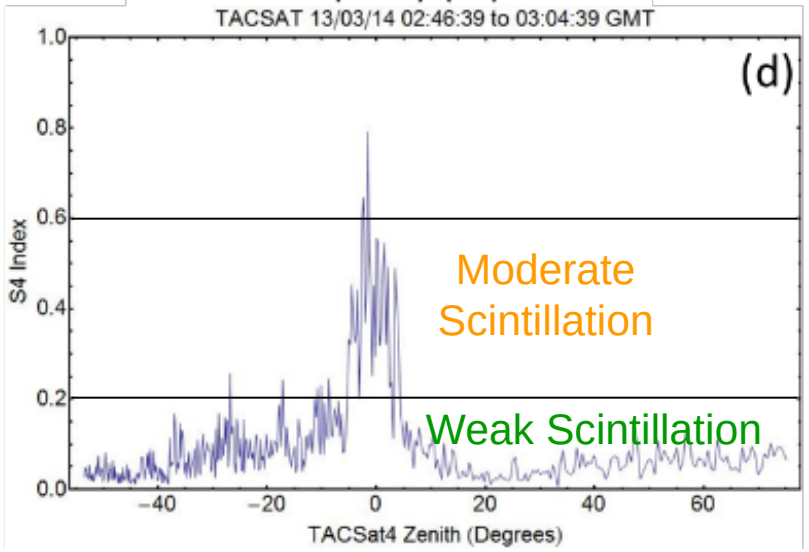


14 March 2012 TACSat4 253 MHz Scintillations
4th (5.8 MHz) Gyro Harmonic HF Continuous Twisted Beam



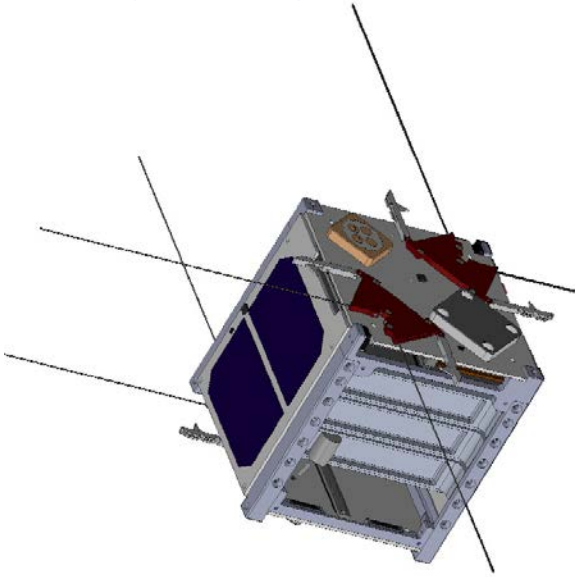


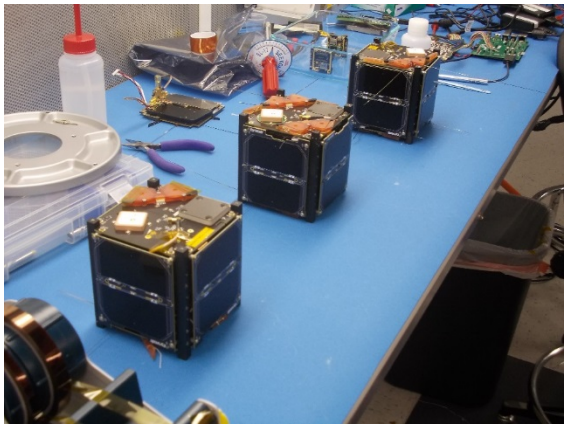




Radio Propagation CubeSat: PROPCUBE

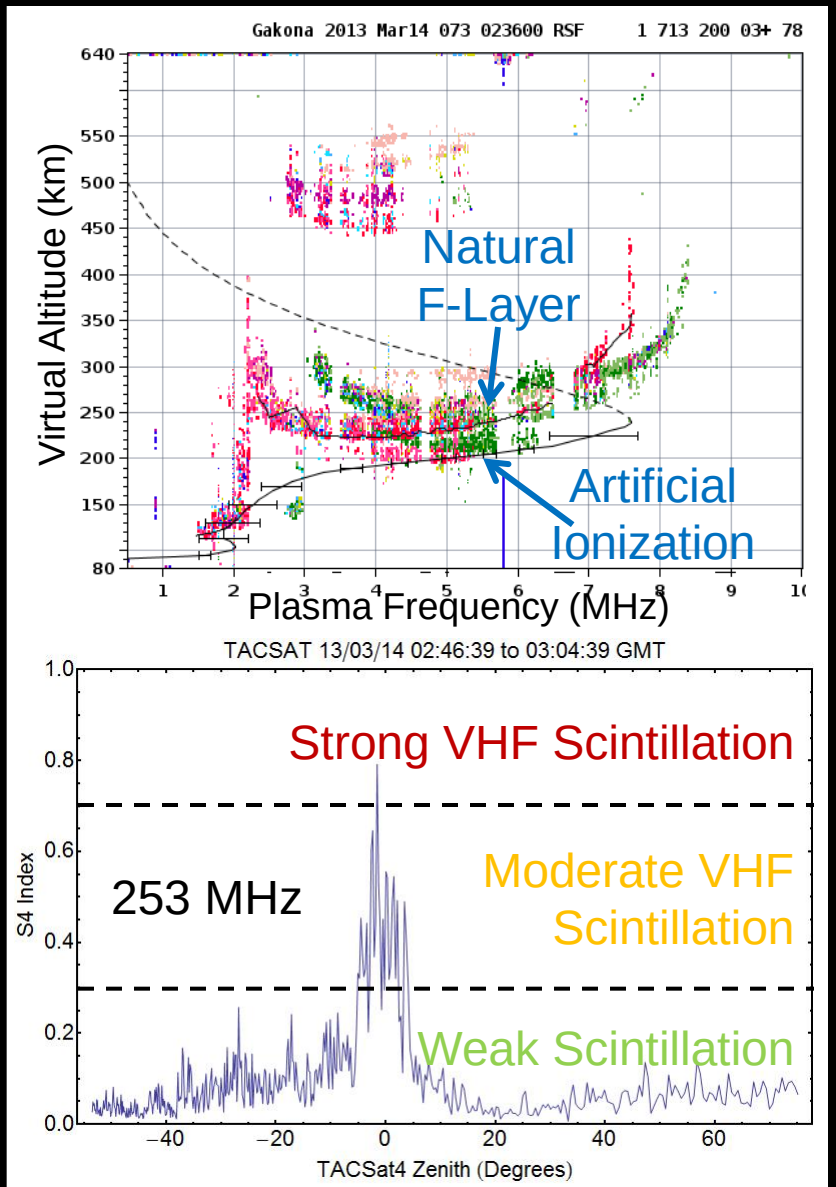
- PROPCUBE
  - 380 to 400 MHz UHF Band
  - 2340 to 2380 MHz S-Band
  - Frequency Pairs: (2340/390) = (2346/391) = (2352/392) … (2376/396) = 6
- Launch Schedules
  - 13 July 2015 (PROPCUBE-2 Fauna) 51.6 Degree Inclination Space-X
  - 27 September 2015 (PROCUBE-1 Flora and PROPCUBE-3 Meriwether) 63 Degree Inclination for HAARP
- Ionospheric Electron Density and Irregularities
  - Total Electron Content by Differential Group Delay
  - Plasma Irregularities by Amplitude and Phase Scintillations
  - Detection of Artificial Ionization/Irregularities Generated by HAARP, Arecibo, SURA





Artificial Ionization Clouds in Near-Earth Space

- Goal: Understand the Physics for RF Generation of Artificial Plasma Clouds in the Upper Atmosphere
- Current Artificial Ionization (AI) Technique
  - High Power Radio Waves Tuned to Electron Gyro Frequency Harmonics
  - Single Mode “Pencil Beam” on the Bottomside Ionosphere
  - Limited Duration and Stability of Artificial Ionization Clouds
- Improved AI Technique Developed by NRL
  - Employ “Twisted Beam” of High Power RF
  - Tune to 2nd, 3rd, 4th, 5th or 6th Electron Cyclotron Harmonic at Selected Altitude
  - Decrease Breakdown Power Requirements with Seed Ionization Clouds
- Theoretical Support of Concept
  - Electromagnetic Models of Pump Wave Propagation and Electrostatic Wave Generation
  - Electron Acceleration Model Leading to Enhanced Ionization
  - Full Wave Simulations of HF Wave Self-Action with AI Clouds
- Experimental Support of Concept
  - Demonstration of Long Duration AI Cloud Using HAARP in Alaska
  - Radio Wave Diagnostics of Stimulated Electromagnetic Emissions and Enhanced VHF/UHF Scintillations.
- Localized Control of Ionospheric Propagation by AI
  - New HF Reflection Layers Below 200 km Altitude
  - Enhanced Plasma Irregularity Turbulence that Distorts Trans-Ionospheric Radio Signals



(Top) Artificial ionization below the ambient ionosphere generated by HAARP twisted beam tuned to 5.83 MHz. (Bottom) Intense VHF Scintillations from TACSat4 for EM wave propagation through the HAARP modified volume.