Excitation of Magnetospheric Resonators with HAARP

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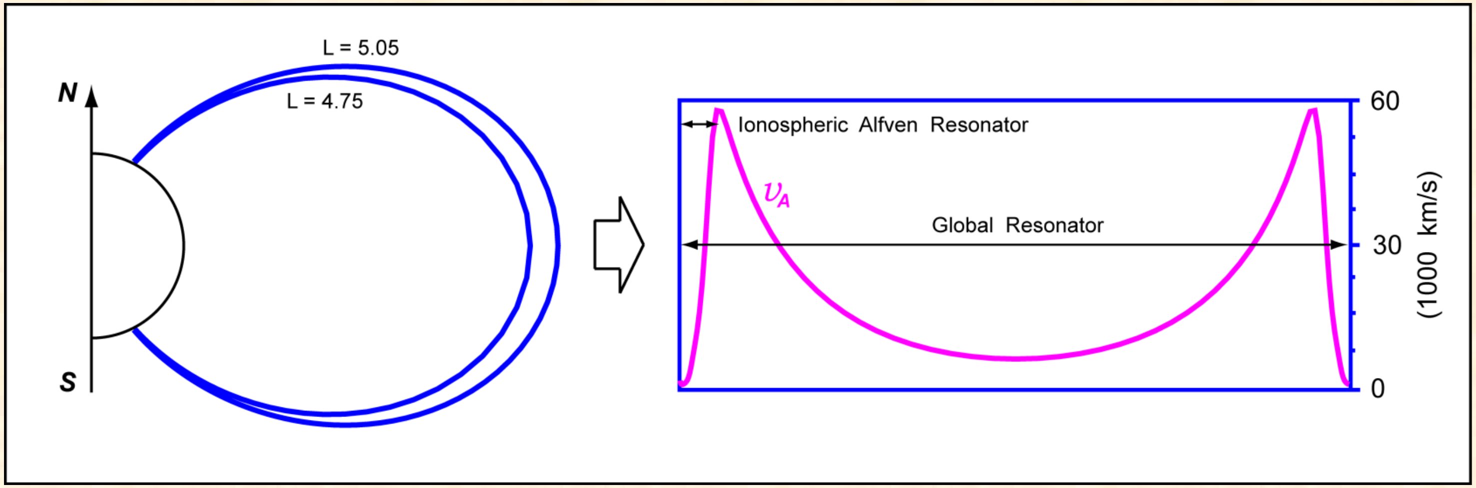
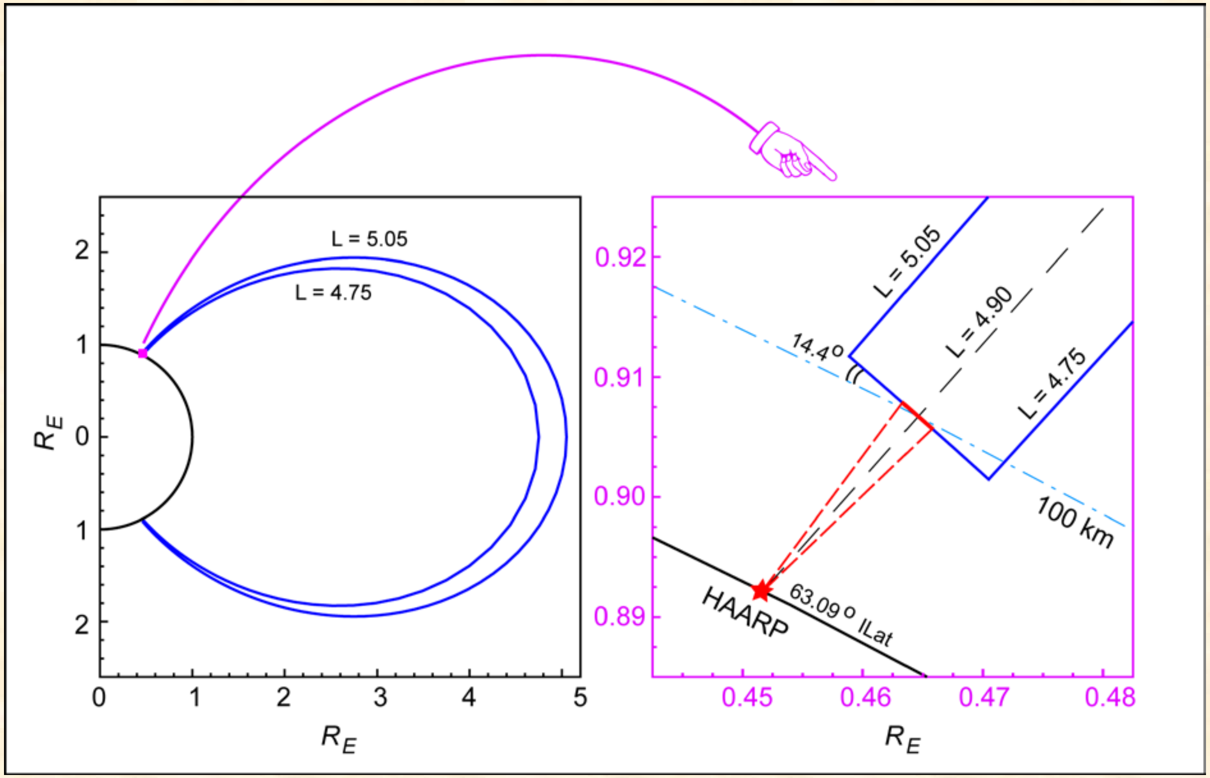
HAARP can excite ULF waves inside 1) Global Magnetospheric Resonator and 2) Ionospheric Alfven Resonator



Mechanism of the wave generation is changing of the ionospheric conductivity by heating the ionosphere with RF waves when the electric field exists there.

Global Resonator

HAARP Heating Experiment



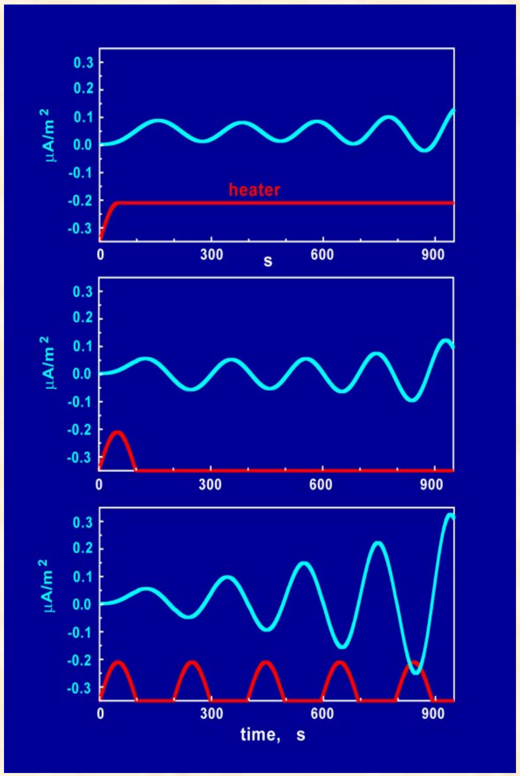
Simulations of different heating regimes for IFI excitation

$$\nabla\cdot[(\Sigma_{P0}+\delta\Sigma_P)\mathbf{E}_{\perp 0}] = -j_{\parallel}$$

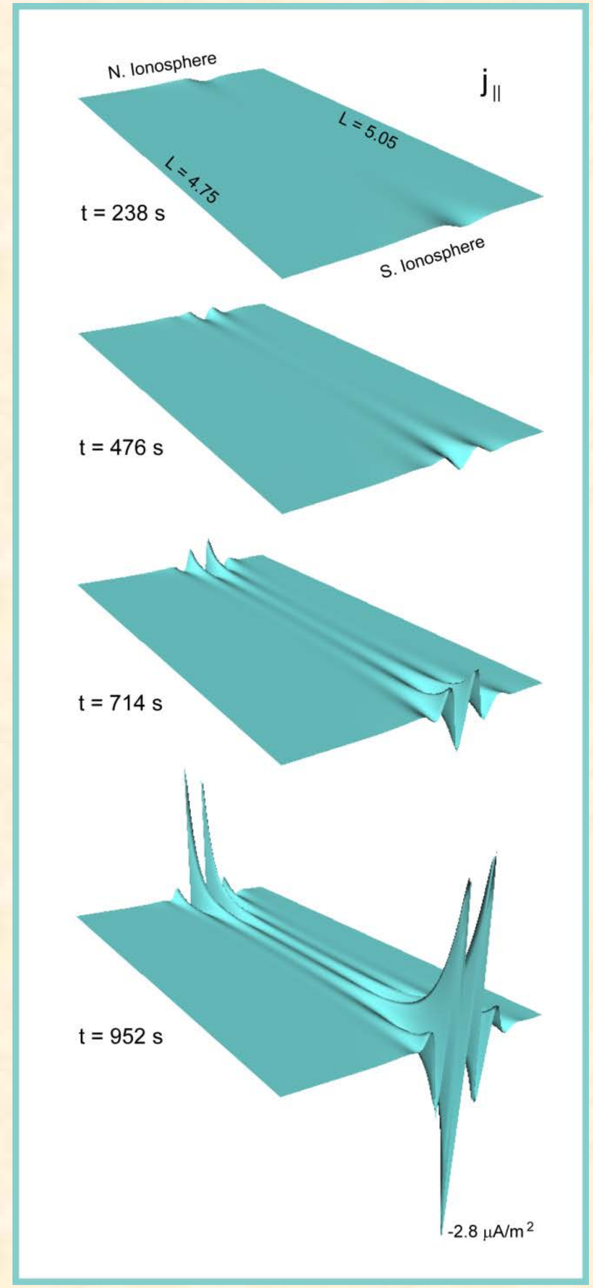
continues heating

single-pulse heating

periodic heating



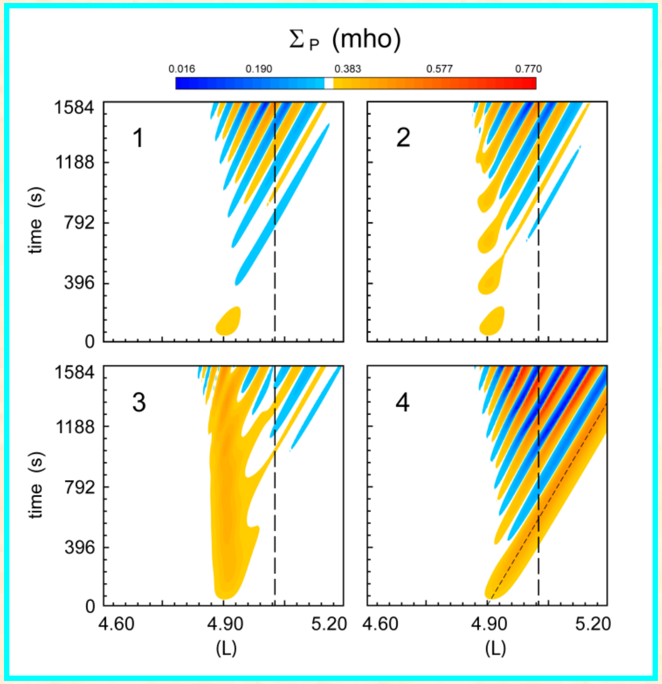
[*Streltsov et al.*, 2005]

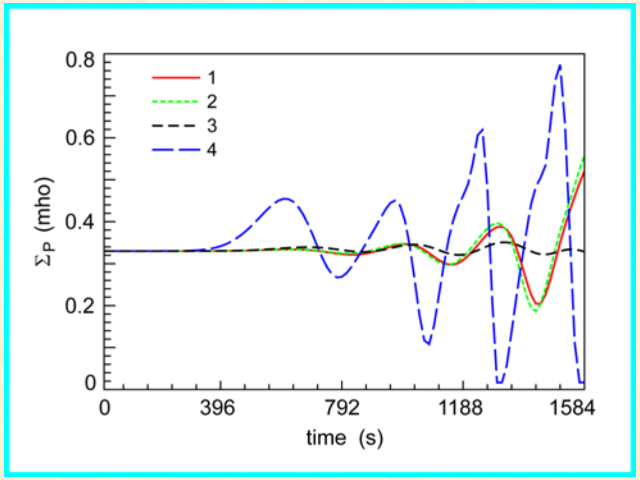


Different Heating Regimes for IFI Excitation

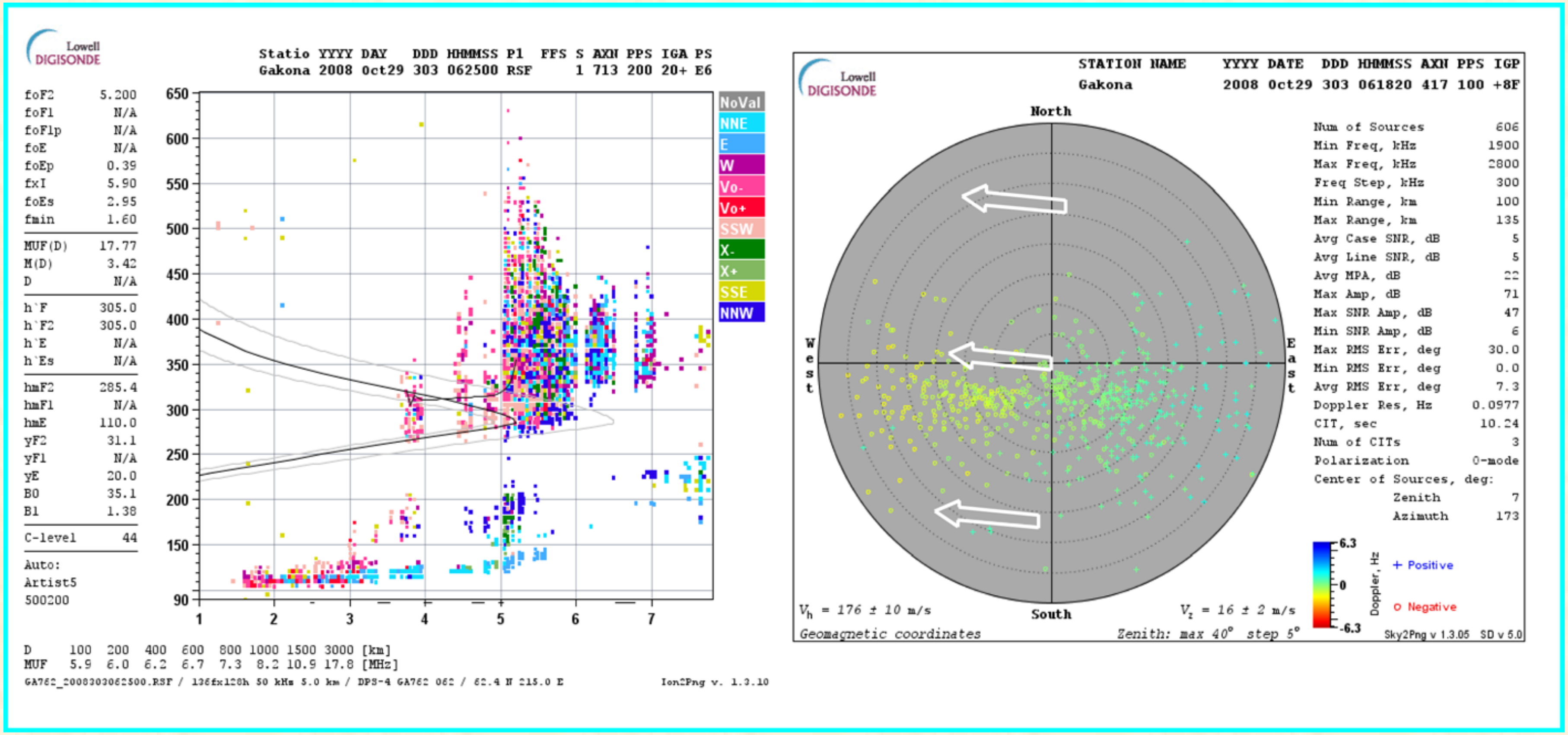
Old approach: heating of the same spot in the ionospehere [*Streltsov et al*., 2005]

New approach: moving the spot with the phase velocity of the wave [*Streltsov and Pedersen,* 2010]



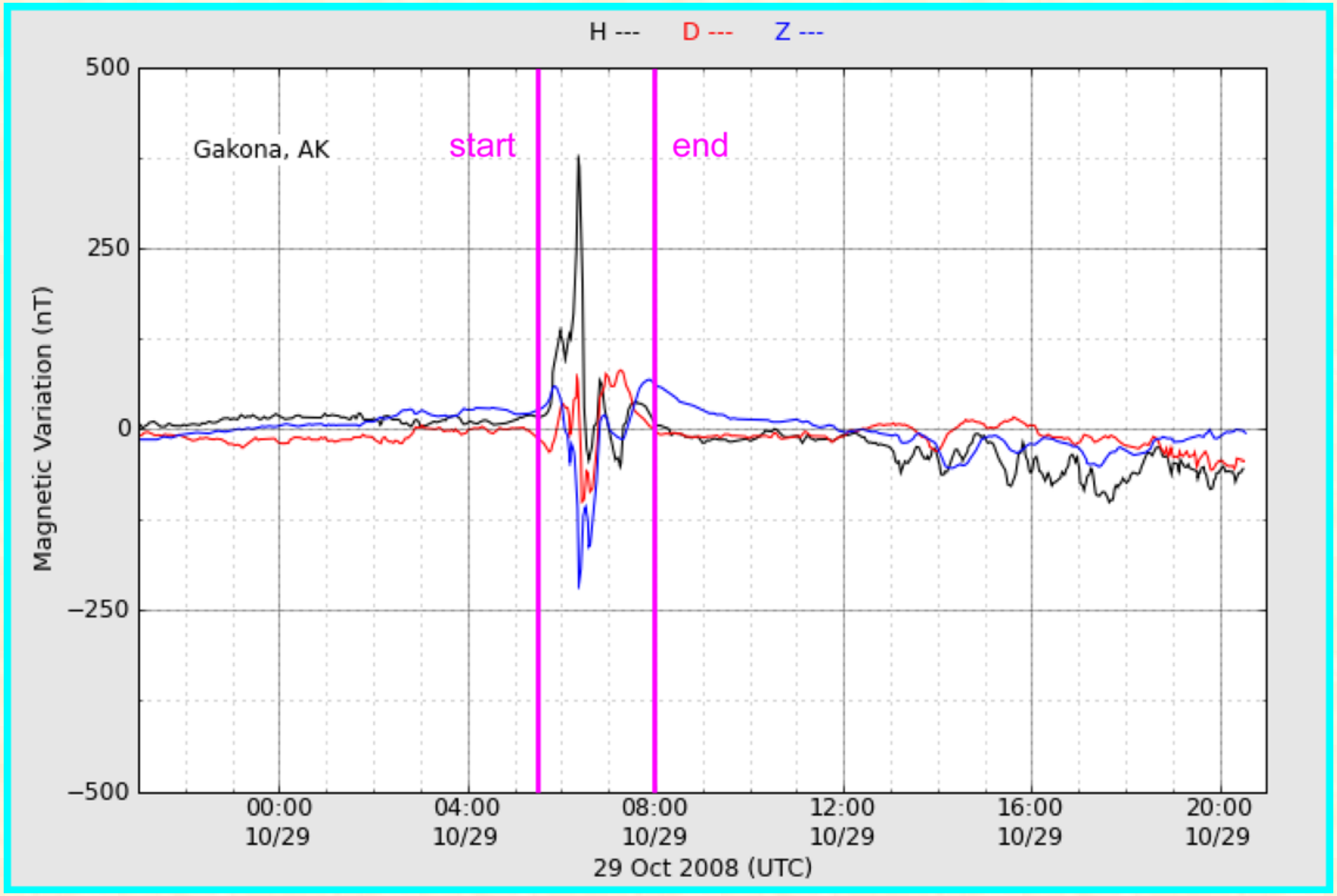


HAARP Experiment 29 Oct 2008



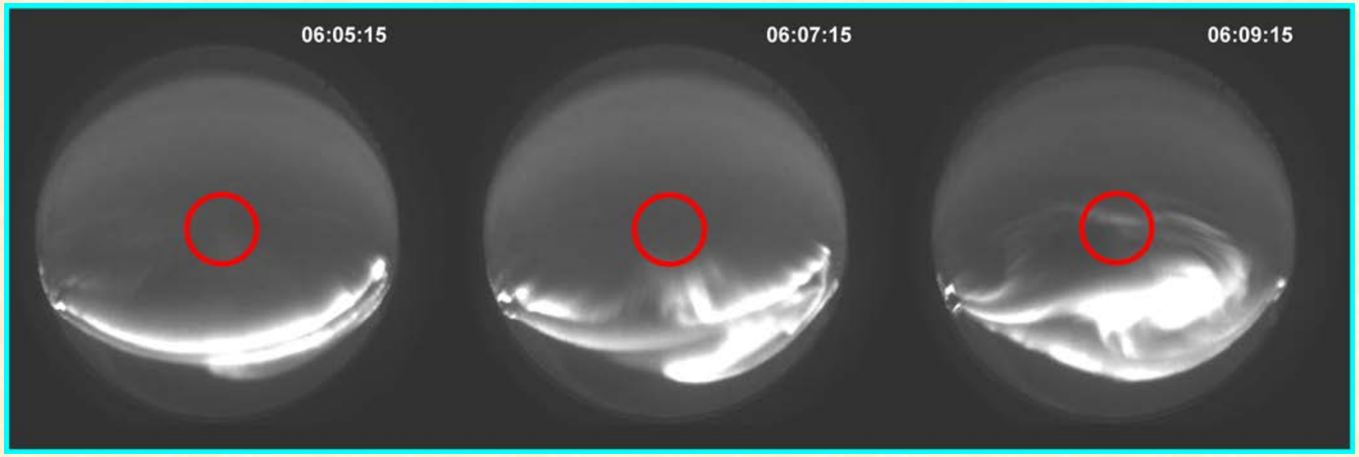
HAARP HF digisonde
(A. Lee Snyder)

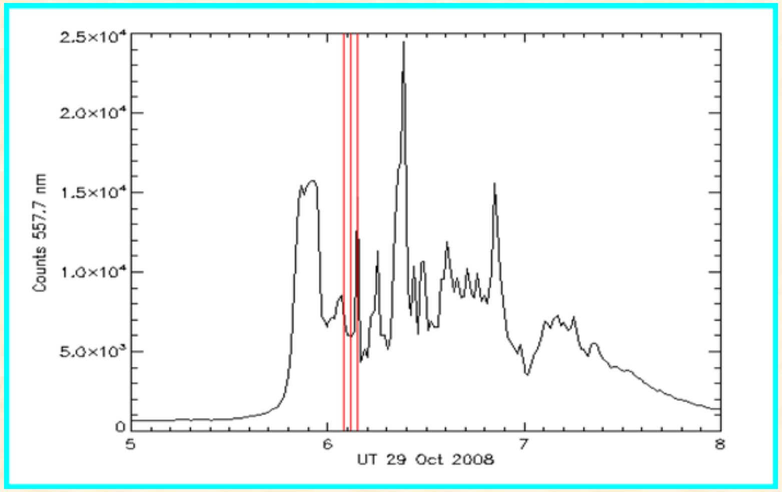
HAARP Experiment 29 Oct 2008



HAARP all-sky imager

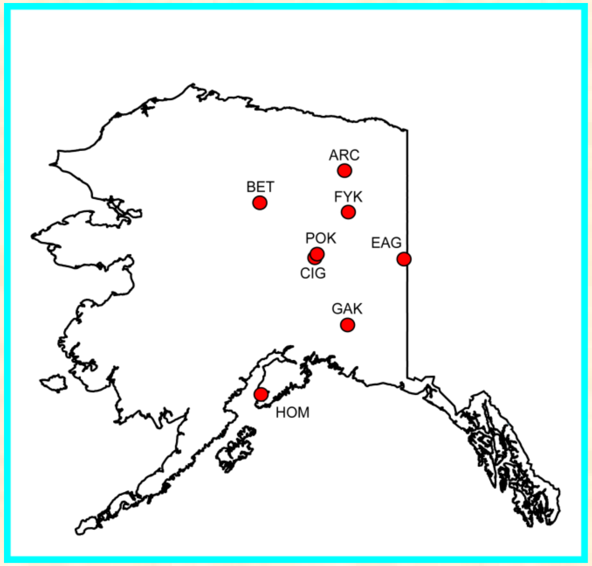
(Todd Pedersen)

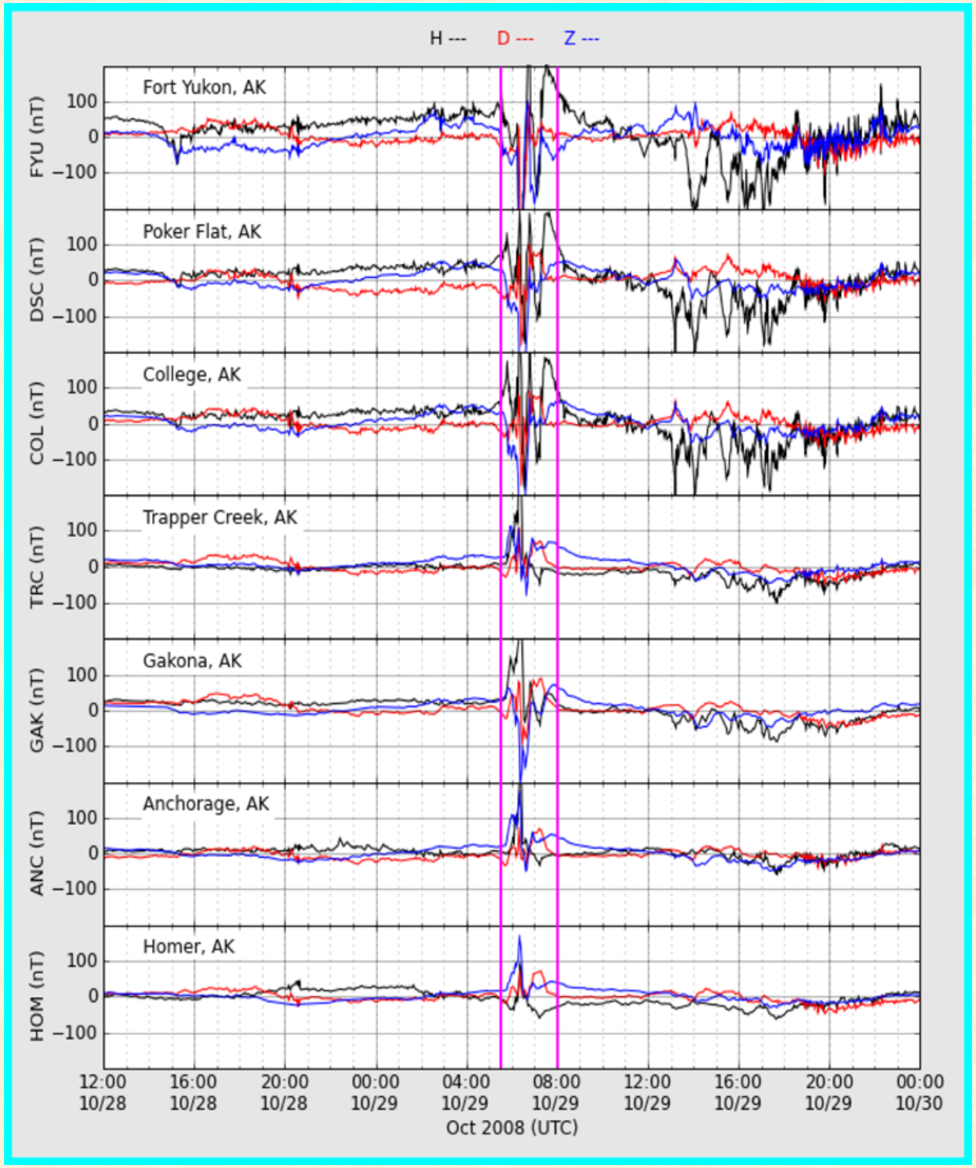




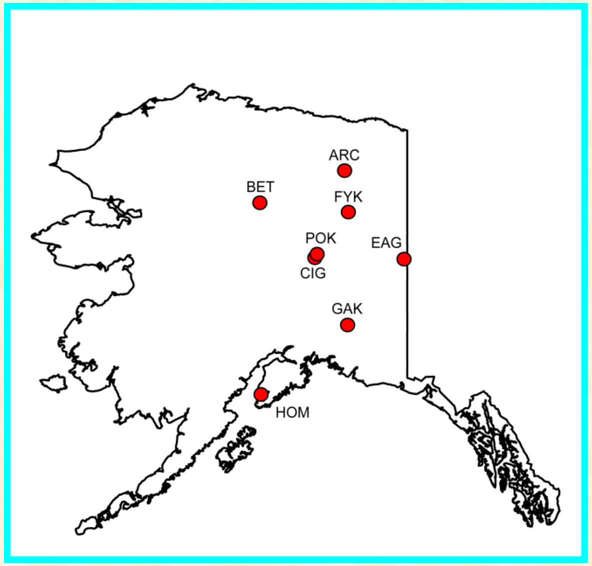
UAF/GI magnetometer array (MAGI)

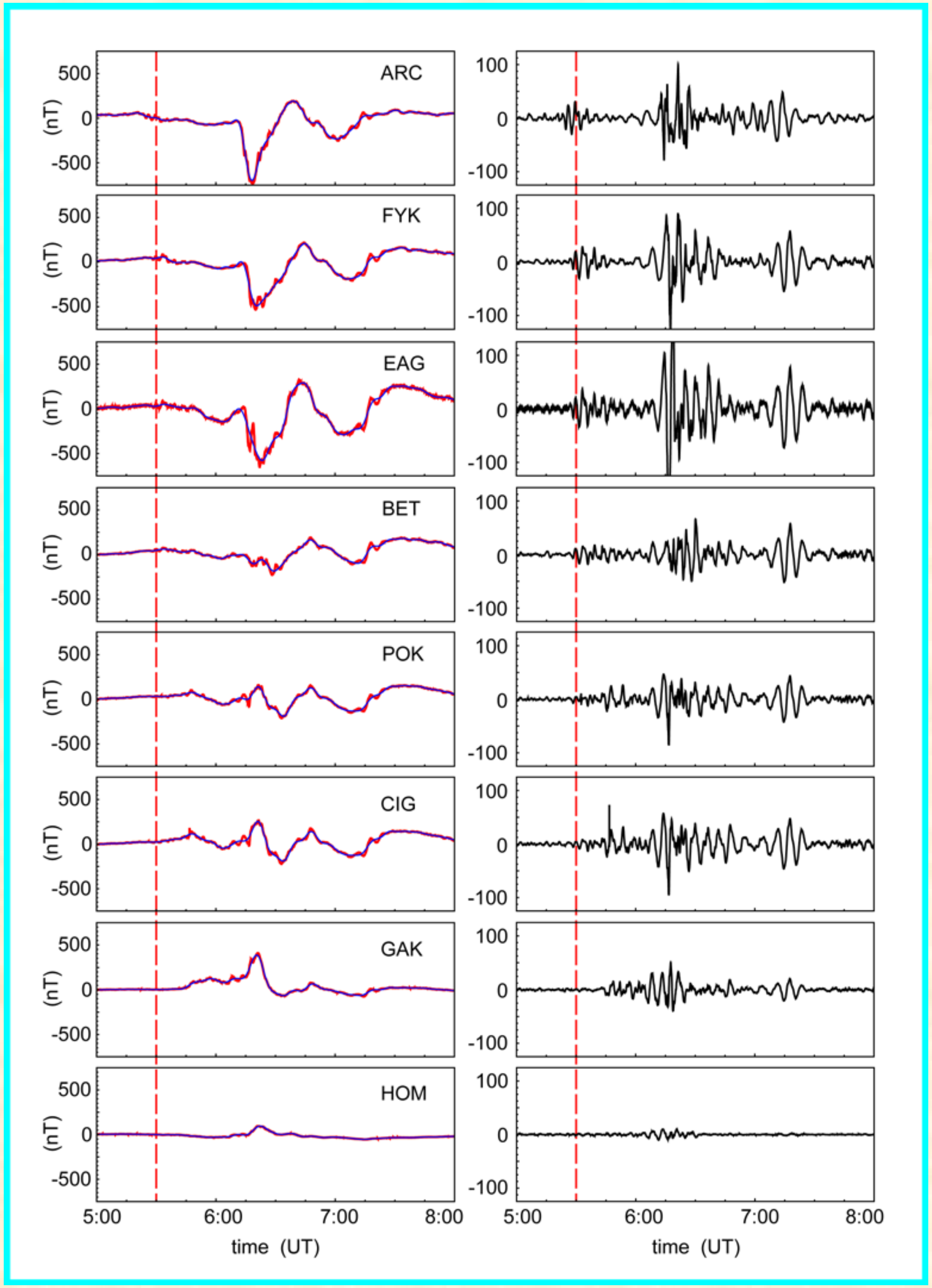
Alaska



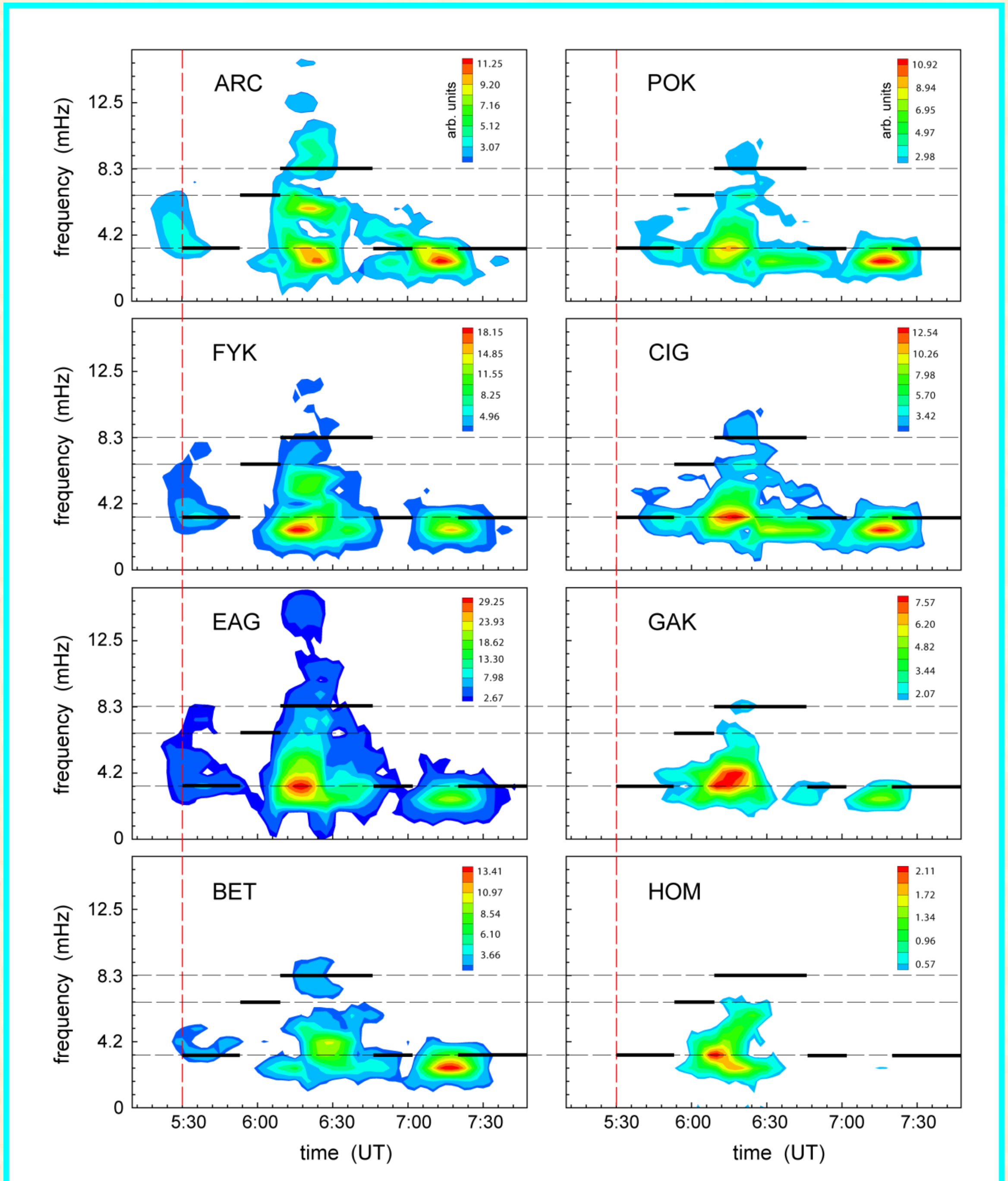


Alaska


ARC
BET
FYK
POK
CIG
EAG
GAK
HOM


ARC
FYK
EAG
BET
POK
CIG
GAK
HOM
(nT)
500
0
-500
100
-100
5:00
6:00
7:00
8:00
time (UT)

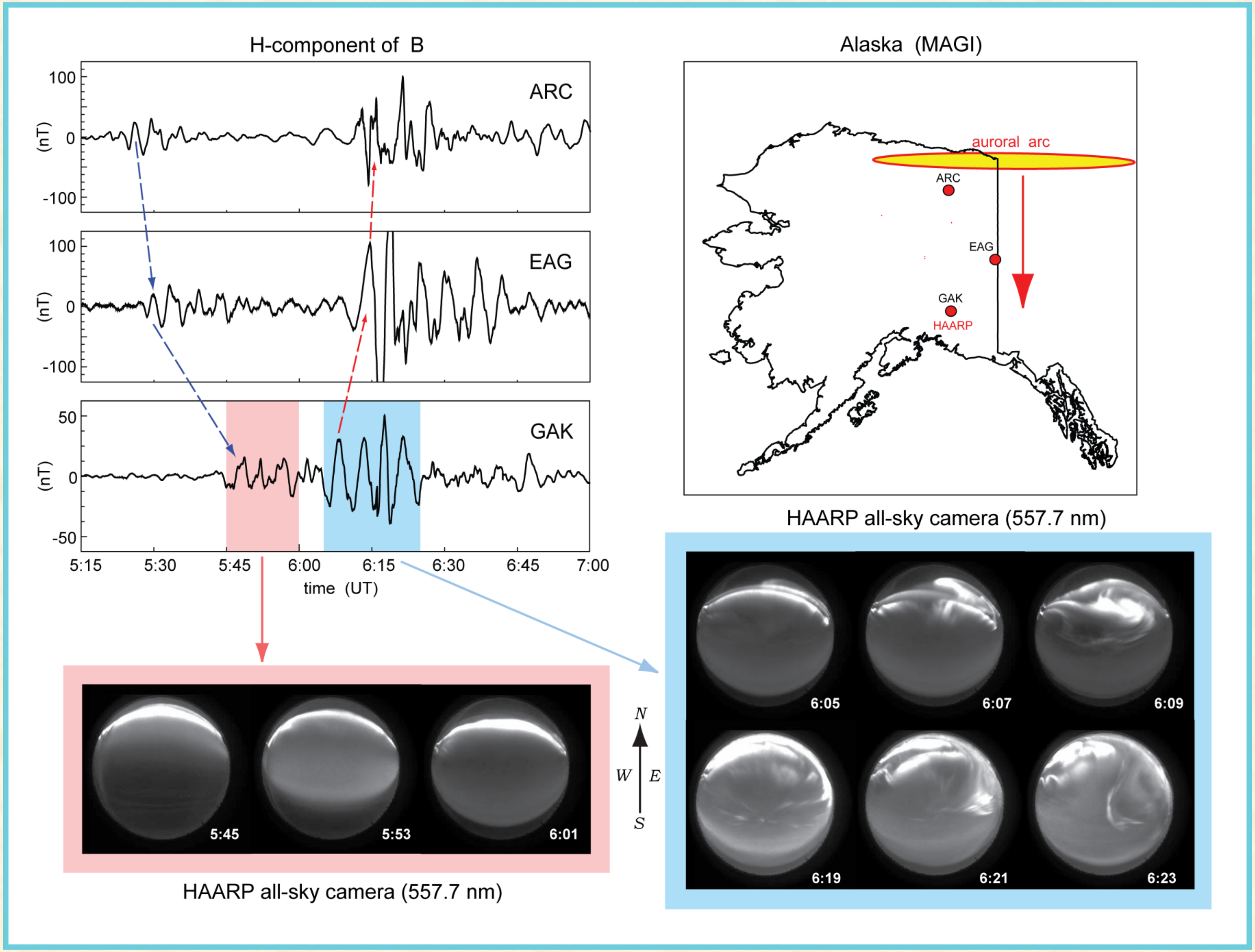
M
A
G
I

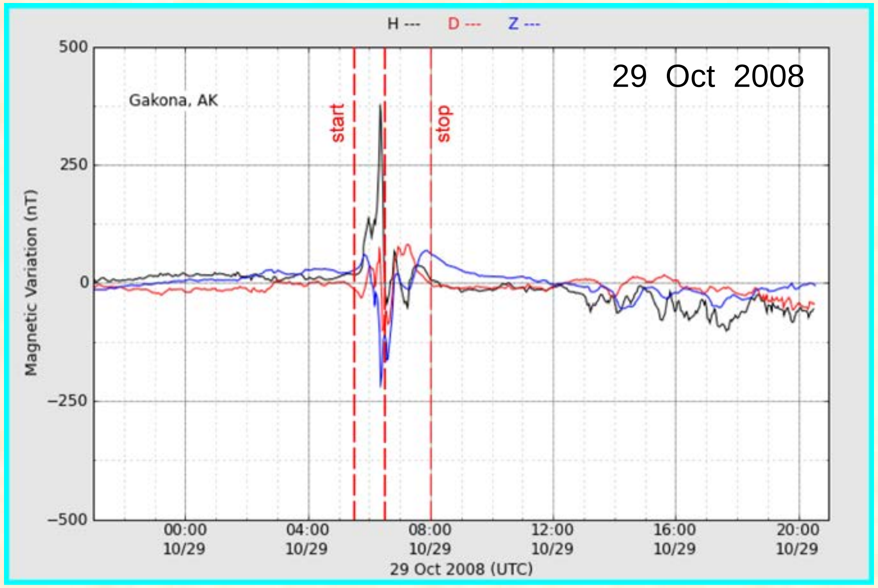


ARC
POK
FYK
CIG
EAG
GAK
BET
HOM
arb. units
11.25
9.20
7.16
5.12
3.07
10.92
8.94
6.95
4.97
2.98
18.15
14.85
11.55
8.25
4.96
12.54
10.26
7.98
5.70
3.42
29.25
23.93
18.62
13.30
7.98
2.67
7.57
6.20
4.82
3.44
2.07
13.41
10.97
8.54
6.10
3.66
2.11
1.72
1.34
0.96
0.57
frequency (mHz)
12.5
8.3
4.2
0
5:30
6:00
6:30
7:00
7:30
time (UT)

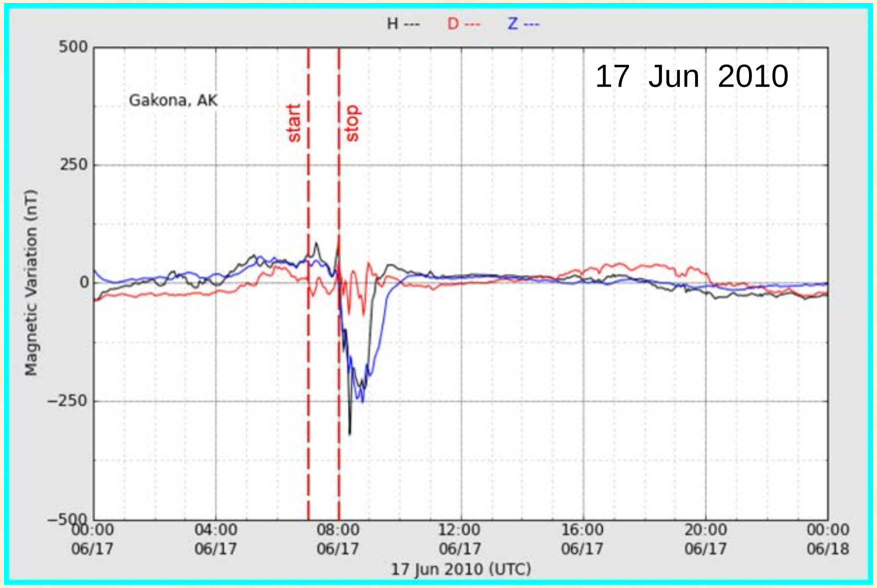
M
A
G
I

This is how it happens …

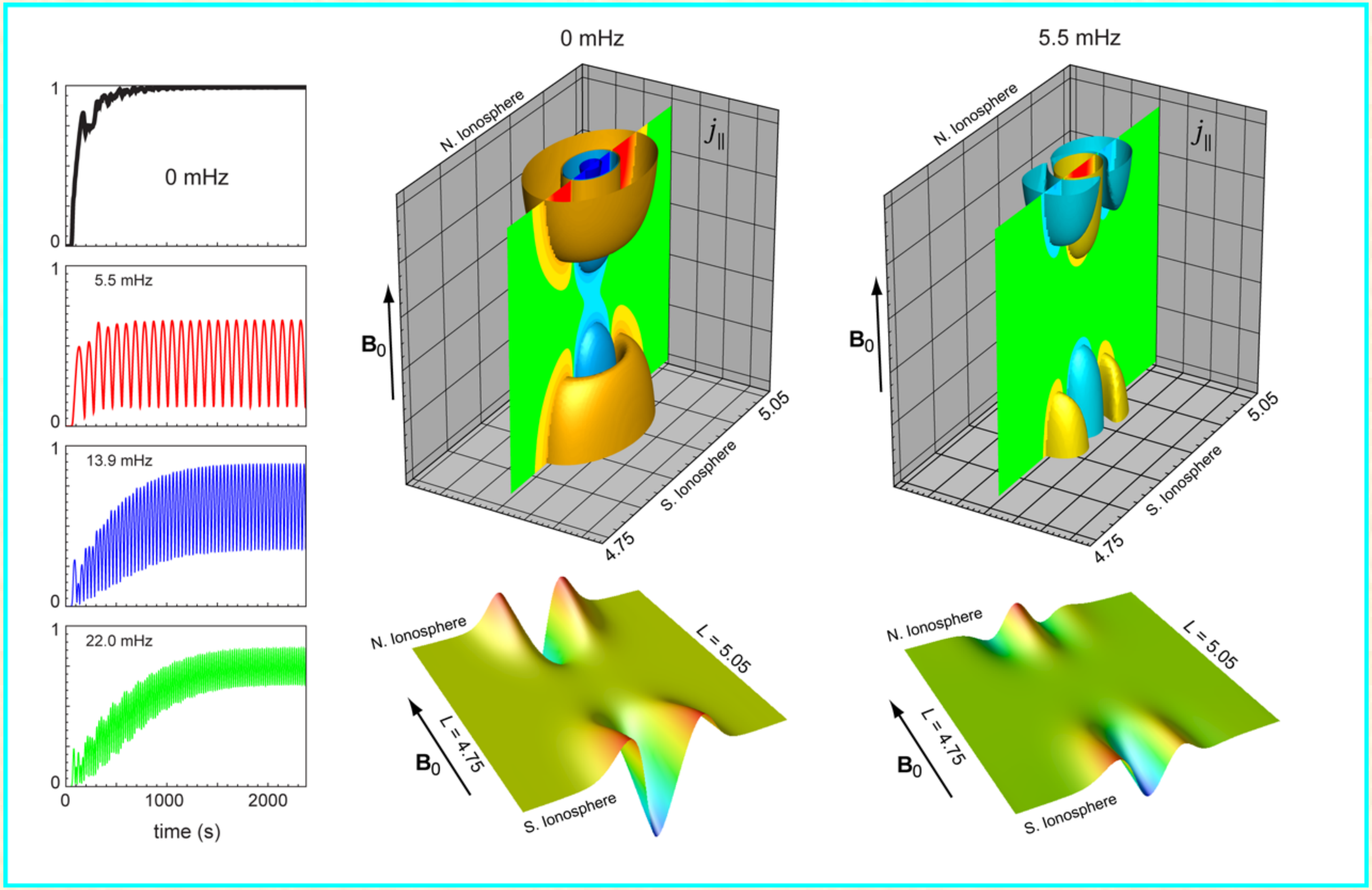



H --- D --- Z ---
29 Oct 2008
Gakona, AK
start
stop
Magnetic Variation (nT)
500
250
0
−250
−500
00:00 10/29
04:00 10/29
08:00 10/29
12:00 10/29
16:00 10/29
20:00 10/29
29 Oct 2008 (UTC)

Substorms

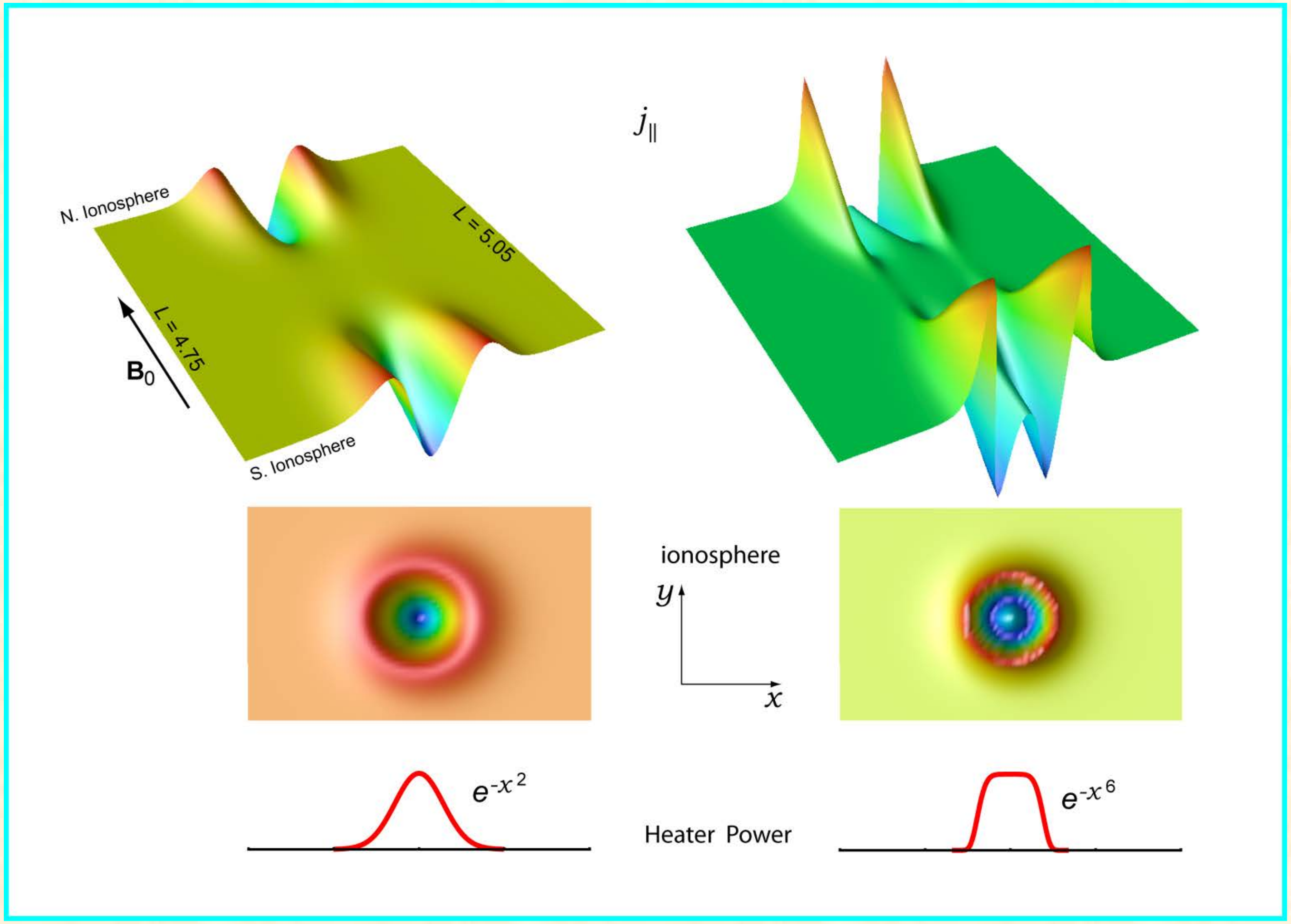

H --- D --- Z ---
17 Jun 2010
Gakona, AK
start
stop
Magnetic Variation (nT)
500
250
0
−250
−500
00:00 06/17
04:00 06/17
08:00 06/17
12:00 06/17
16:00 06/17
20:00 06/17
00:00 06/18
17 Jun 2010 (UTC)

HAARP 3D

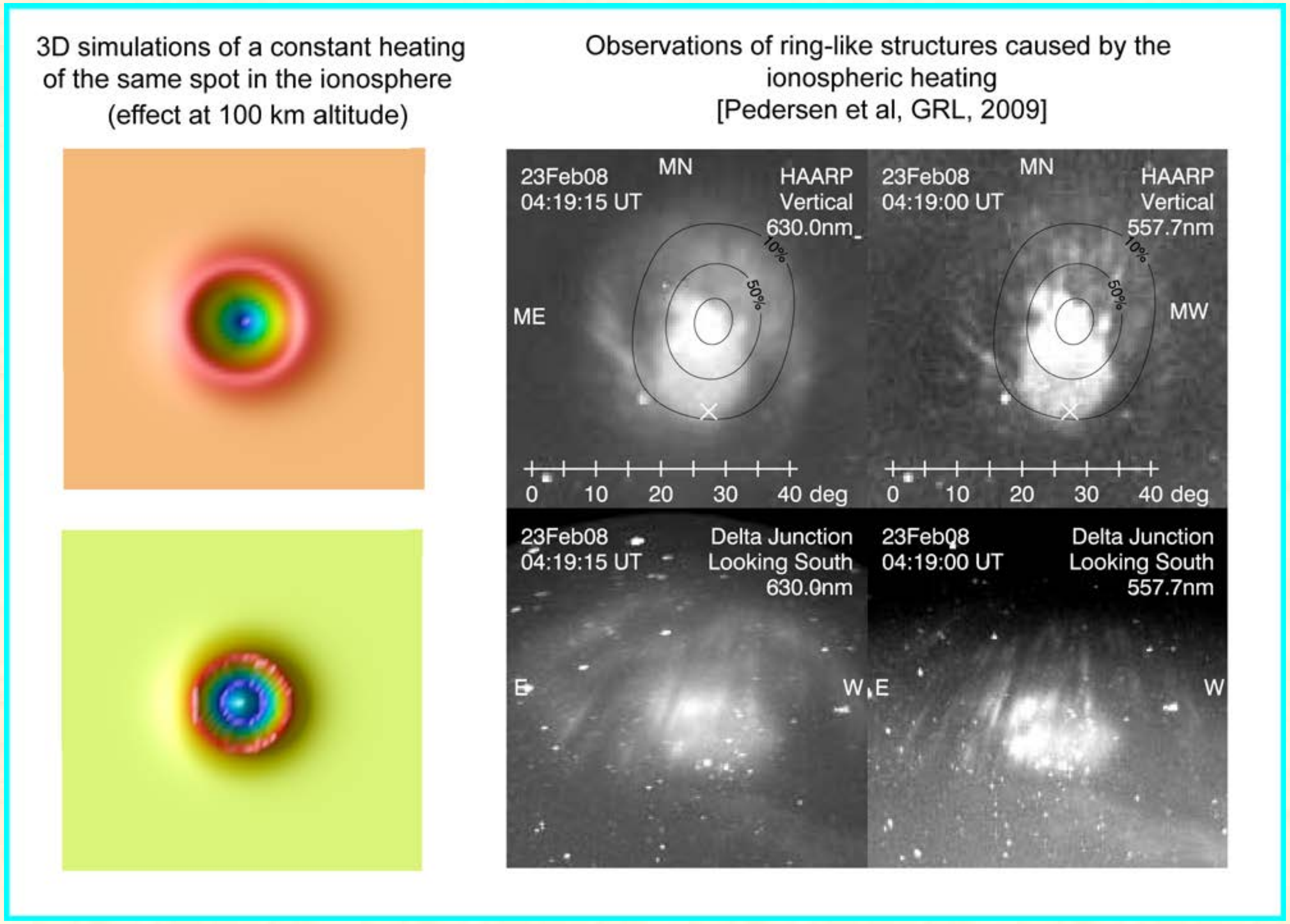


0 mHz
5.5 mHz
1
0
0 mHz
5.5 mHz
13.9 mHz
22.0 mHz
0
1000
2000
time (s)
N. Ionosphere
S. Ionosphere
$j_{\parallel}$
B_0
5.05
4.75
L = 5.05
L = 4.75

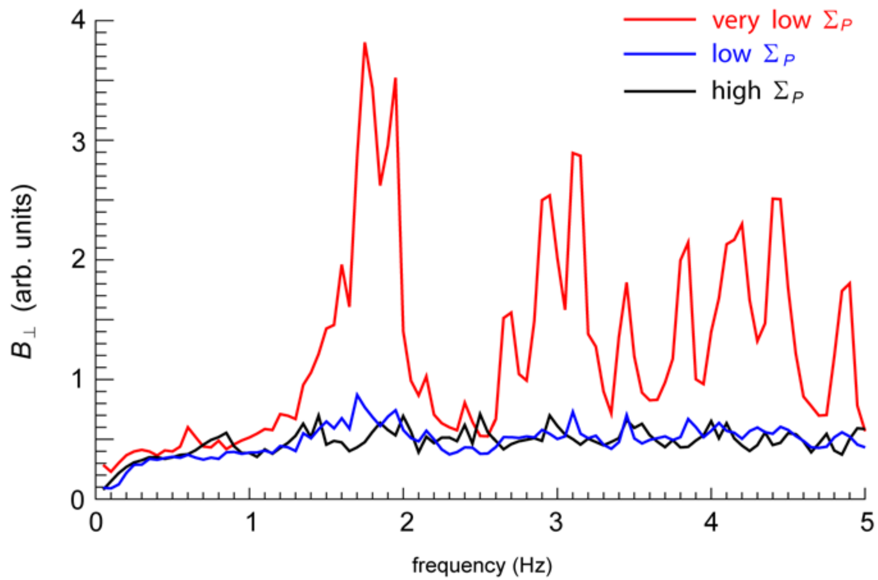
3D simulations of constant heating (high ionospheric conductivity)

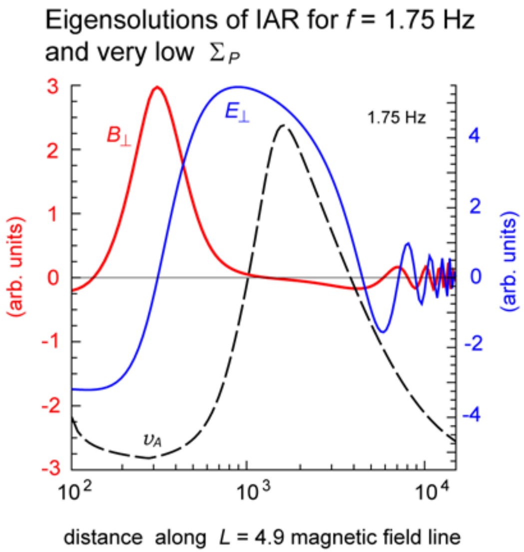


Observations and 3D simulations of effects from the constant heating of F-region



Ionospherc Alfvén Resonator





Wave reflection from the ionosphere:

$$E_{\perp r} = R\, E_{\perp i}$$

$$R = \frac{\Sigma_A - \Sigma_P}{\Sigma_A + \Sigma_P}$$

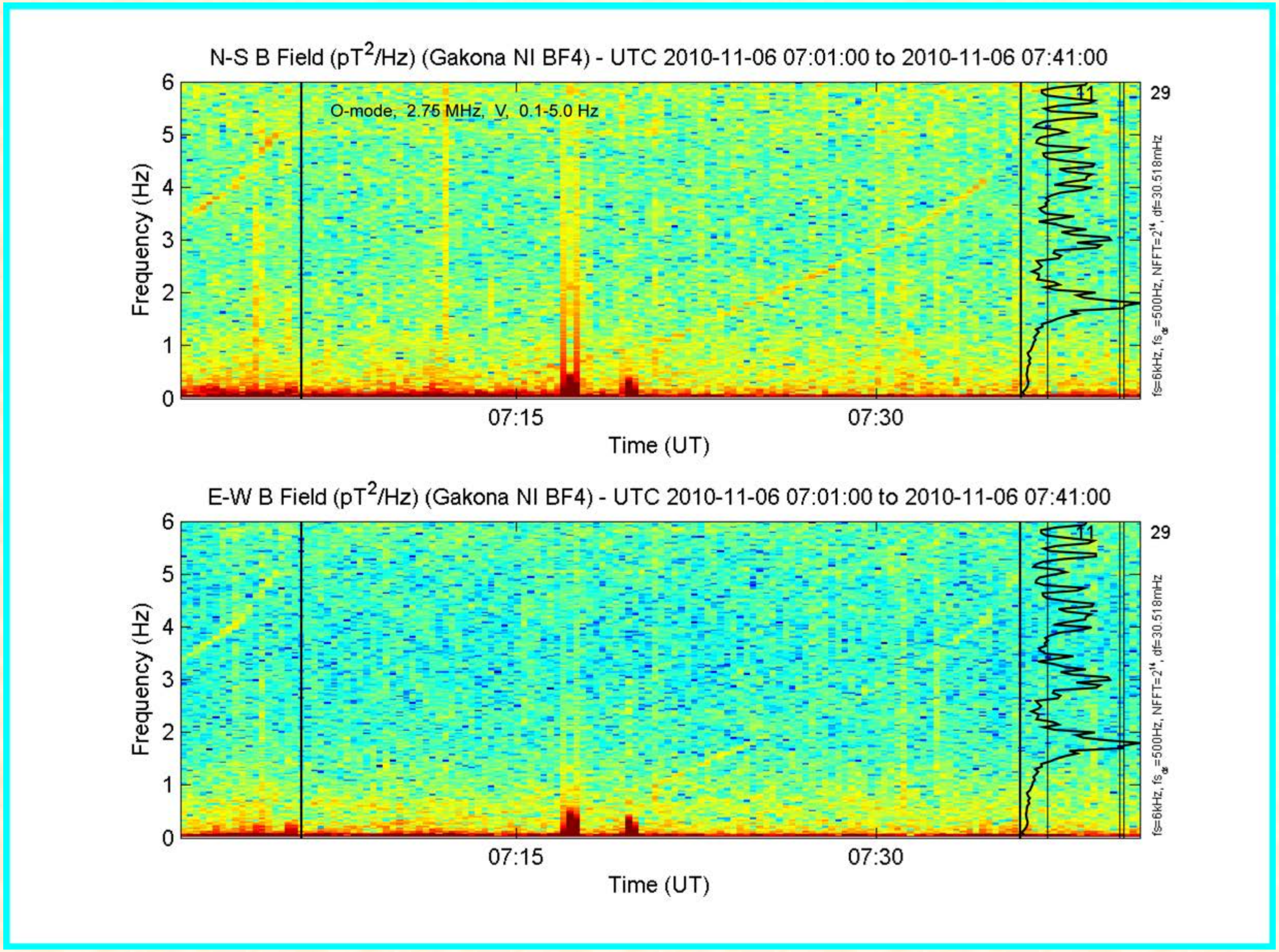
$$\Sigma_A = 1/\mu_0 v_A$$

high Σ_P: **R = -0.310**

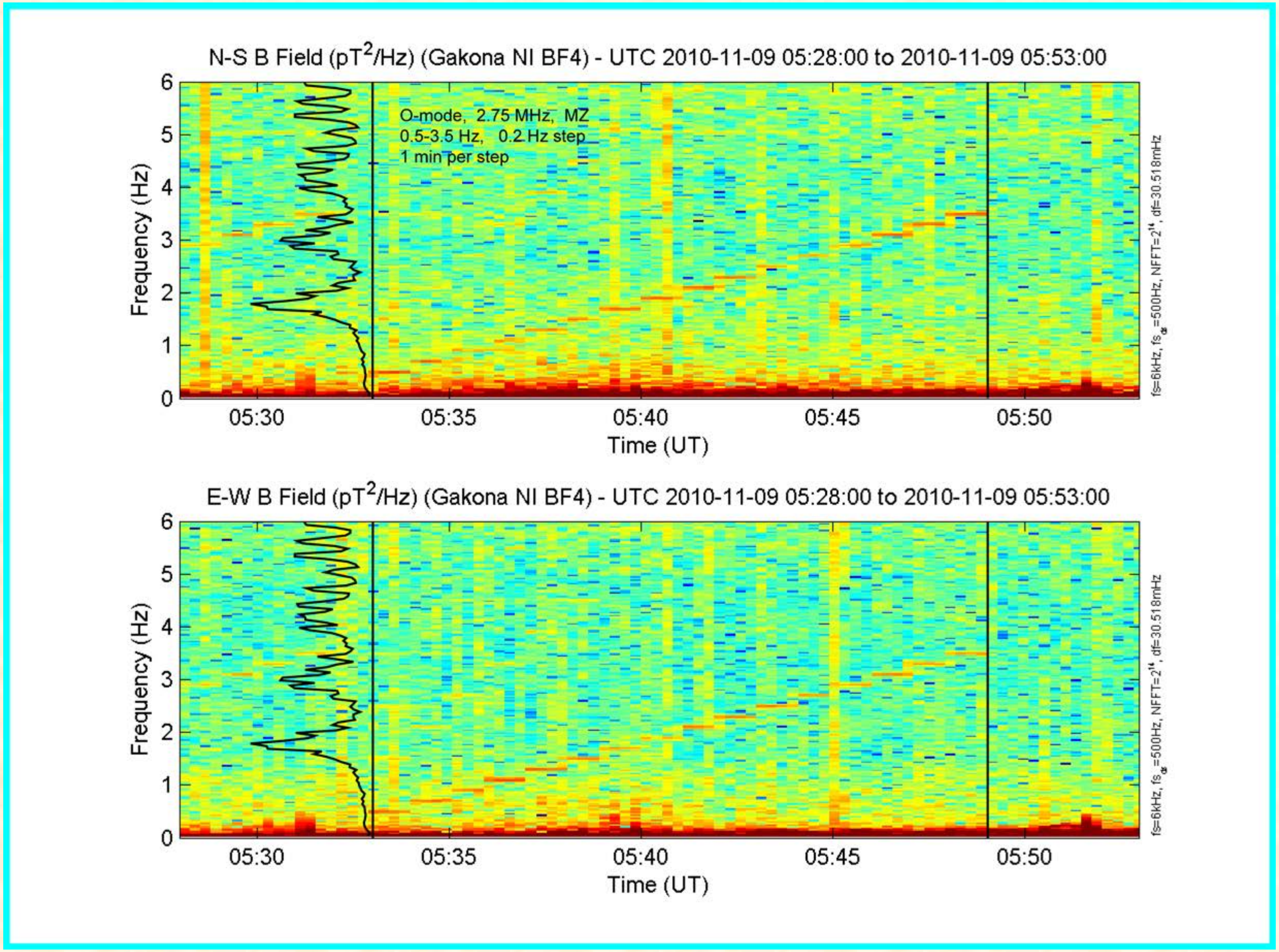
low Σ_P: **R = 0.032**

very low Σ_P: **R = 0.510**

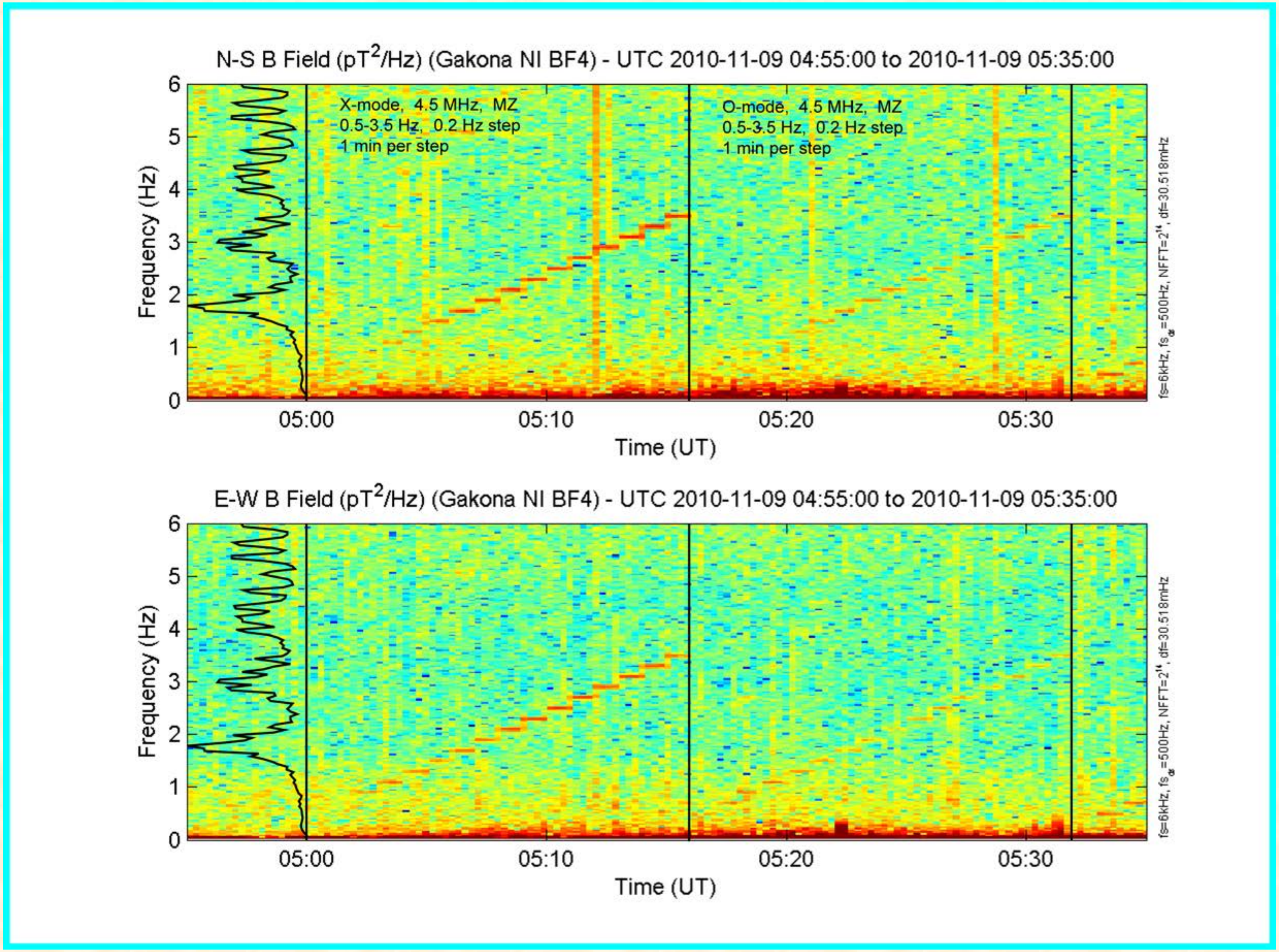
Night (very low conductivity)



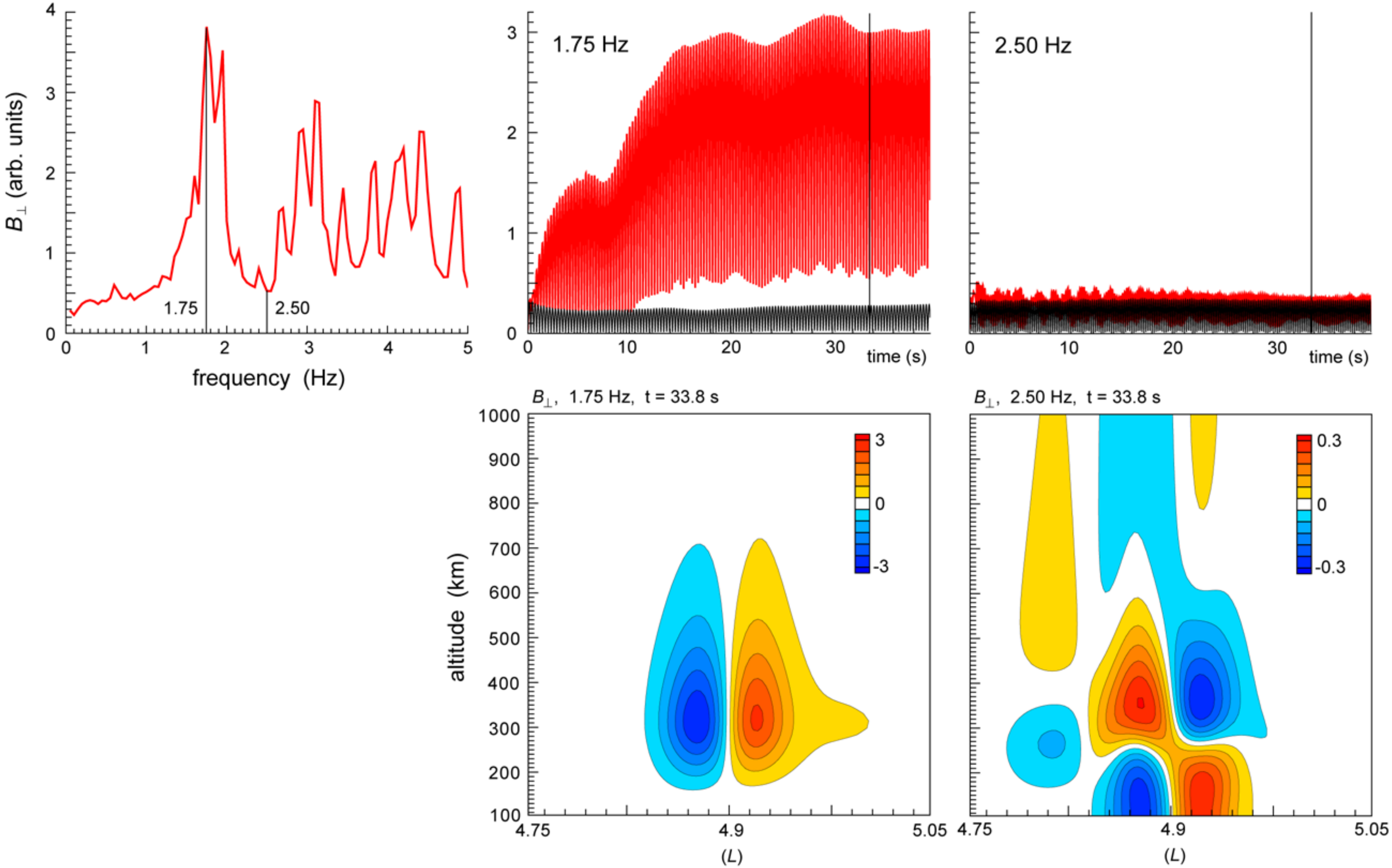
Night (very low conductivity)



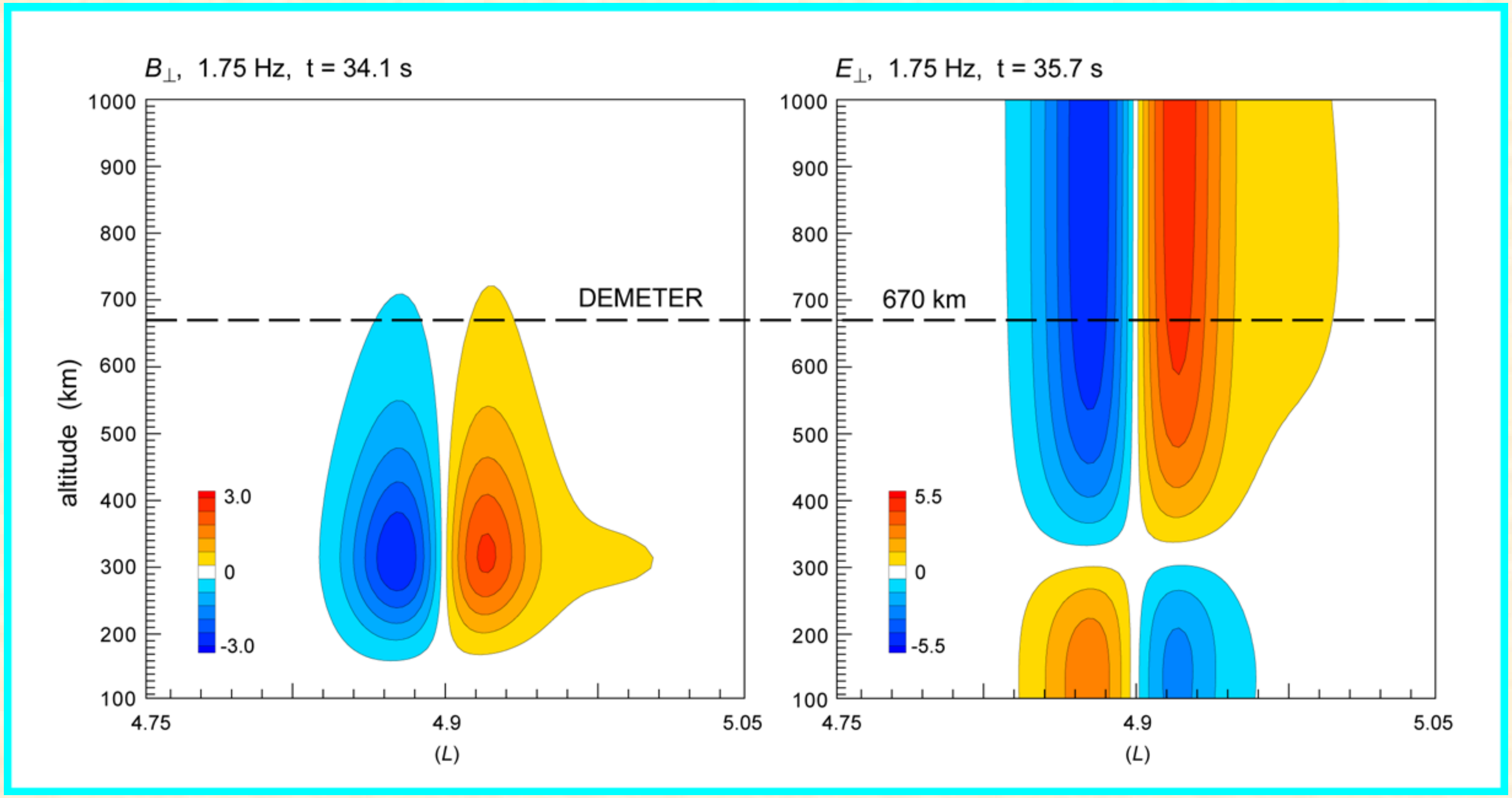
Night (very low conductivity)



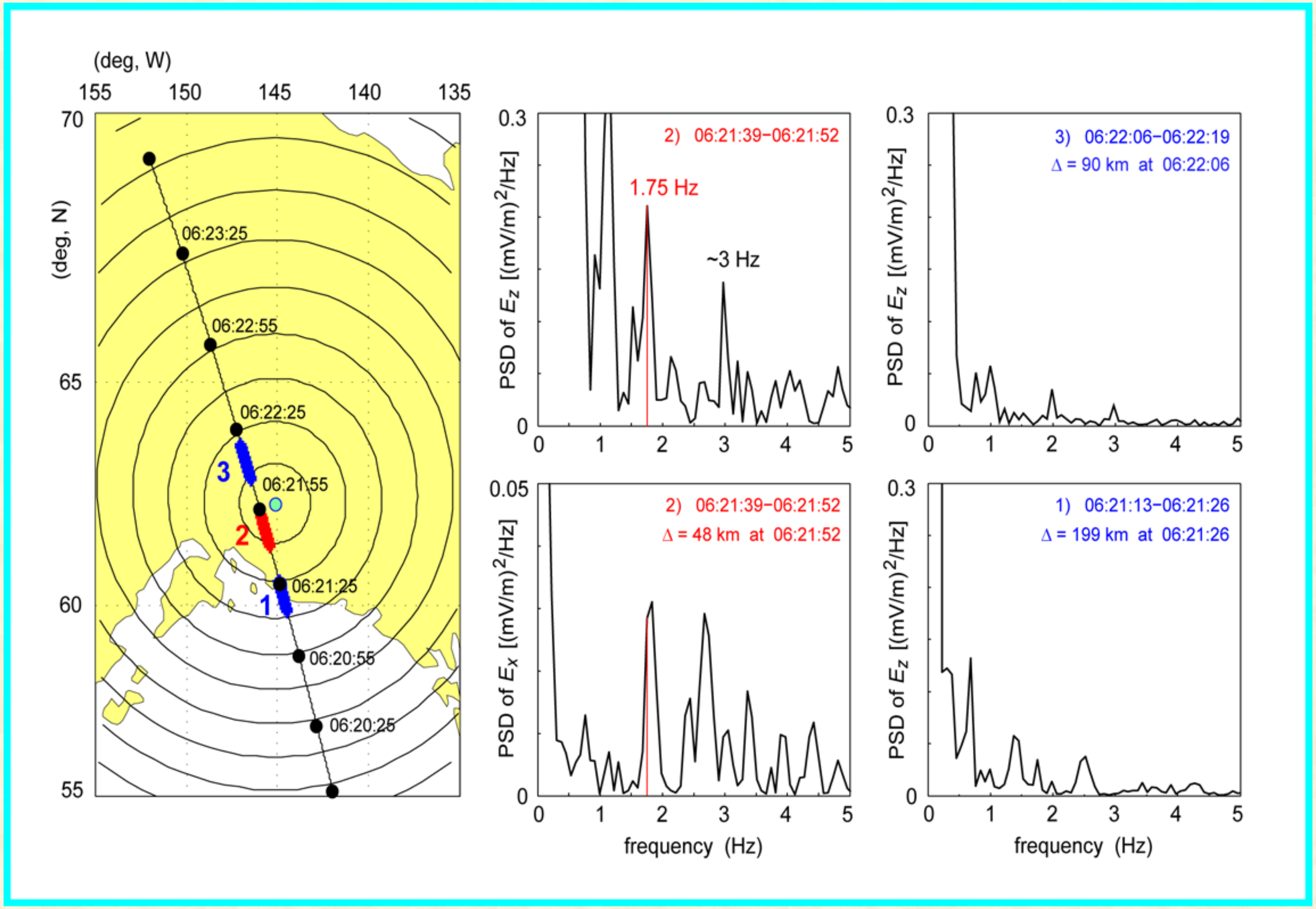
very low conductivity (night)



IAR, very low conductivity, 1.75 Hz



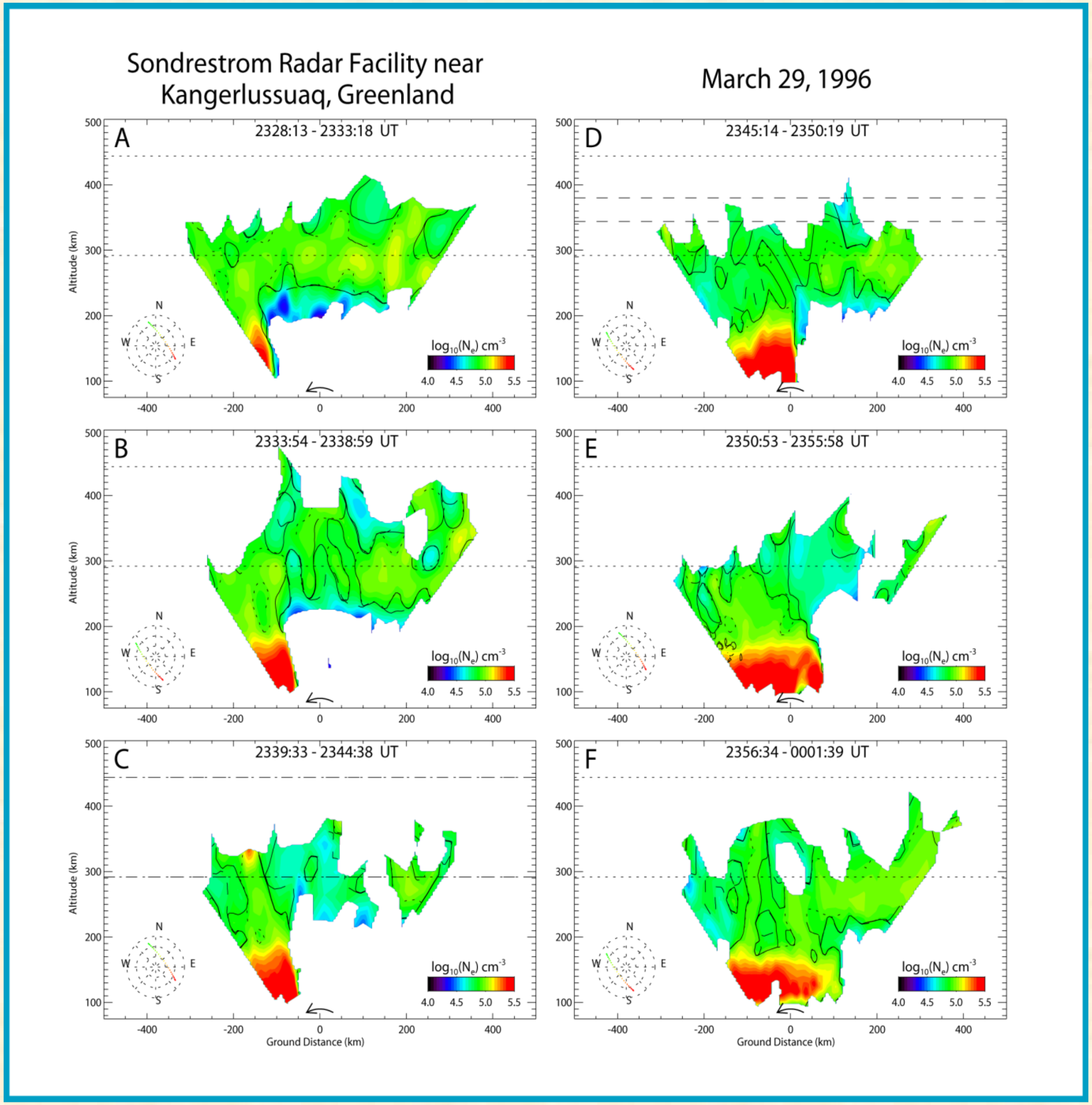
DEMETER - HAARP



Conclusions:

1. HAARP can efficiently generate large-amplitude ULF waves inside the global magnetospheric resonator and inside IAR.
2. The wave generation is most efficient when the ionospheric conductivity is very low (nighttime) and the heating is performed with X-mode waves in a frequency range from 2.8 to 4.5 MHz.
3. The structure of the waves inside IAR does NOT allow to make any conclusions about frequency of the resonator by measuring magnetic signals on the ground.
4. The resonant wave can be determined from measuring electric field on the ground or electric and magnetic field on satellites and/or sounding rockets.

Density cavities in a vicinity of auroral arcs



Shepherd et al. [1998]

Density cavities in the downward current channel