Ionospheric Propagation Mechanisms Revealed with Pactor and OTH Radar

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Collaborators

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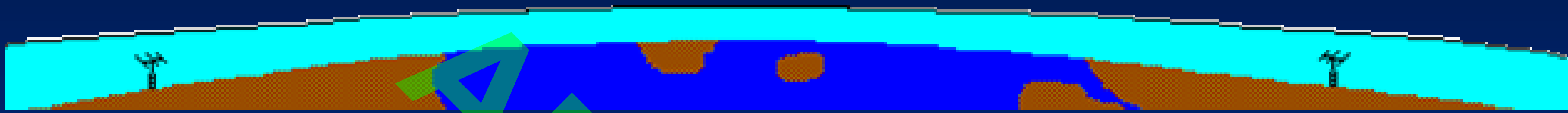
Mode Requirements

1) High sensitivity (Pactor has -18 dB S/N sensitivity - inaudible)
2) Provide accurate time delay readings (Pactor accuracy is 0.625mS)
3) Provide accurate relative Doppler shifts (Pactor accuracy is 35mHz)

HF Station Requirements

1) Consistent readings from HF transceivers (ICOM-746 and Rohde-Schwarz XK-2100)
2) Highest gain with minimum directivity
3) Base stations utilized Zepp antennas
4) Mobile stations utilized all-bander SG-303 verticals with SG-231 autotuners

Establishing a Pactor Contact

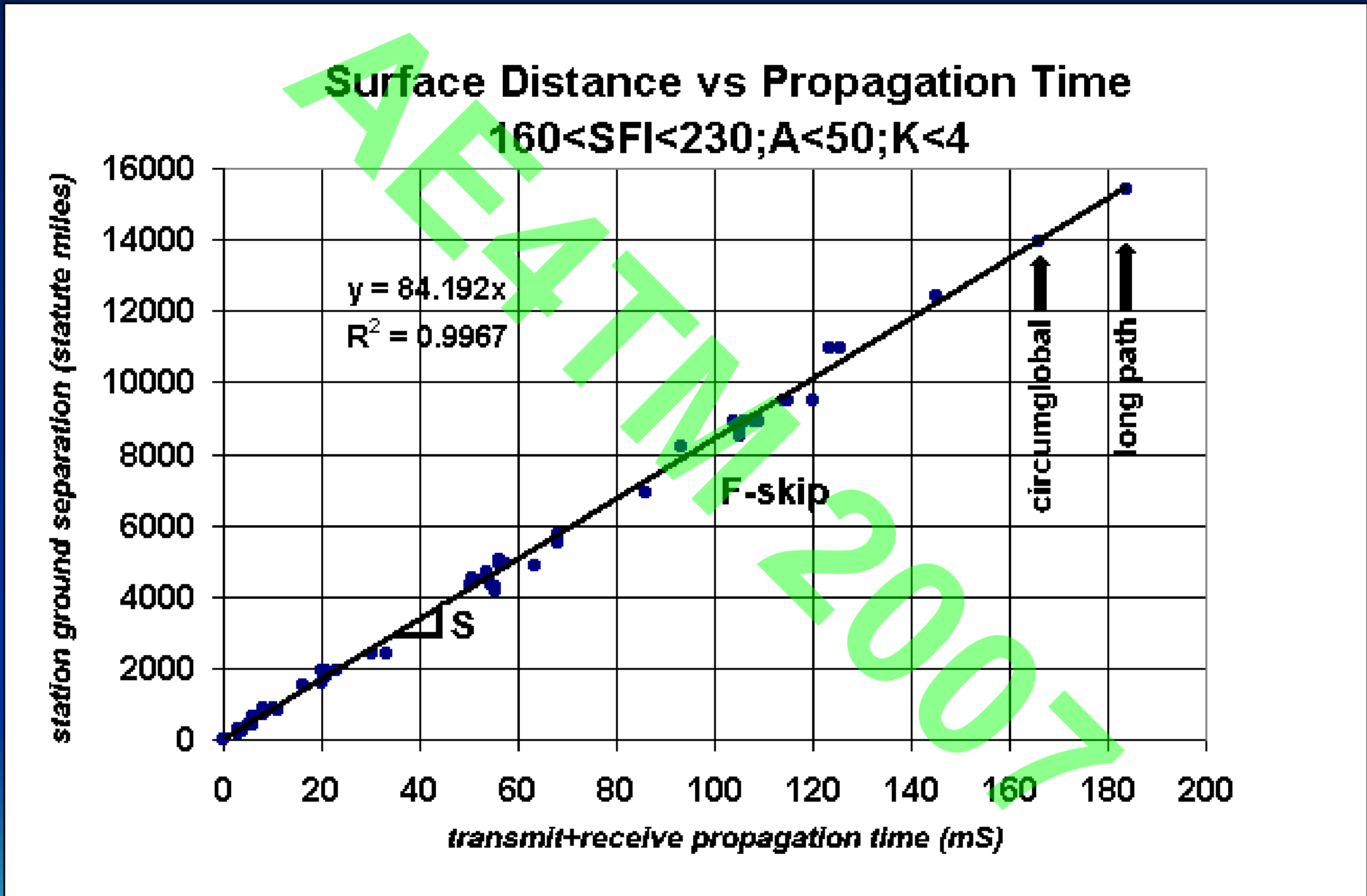


1) Master station ae4tm-1 sends a connect request to a monitoring slave station, e.g. C ae4tm-2.
2) If heard by slave station ae4tm-2, an “ack” is returned.
3) The Pactor controllers begin error free CRC handshaking.
4) The propagation time delay is recorded for error corrections (this data is available for propagation time calculations).
5) The relative frequency difference is updated with each packet burst for the error correction (this data is available for experiments).

Calculating Propagation Distance

- Must subtract time delay from the station electronics: typical delays ~ 55mS.
- Delay (mS) = 21mS + CSD(mS) + IRD_m + IRD_s
- Typical IRD = 3.0mS (SSB IF) – 4.5mS (CW IF)
- D (miles) = 186 mi/mS X t (mS) / 2 (full distance)
- D (miles) = 186 mi/mS X t (mS) / 4 (radar mode)
- $V_{Doppler}$ = (c / 2) X (Δf / f)

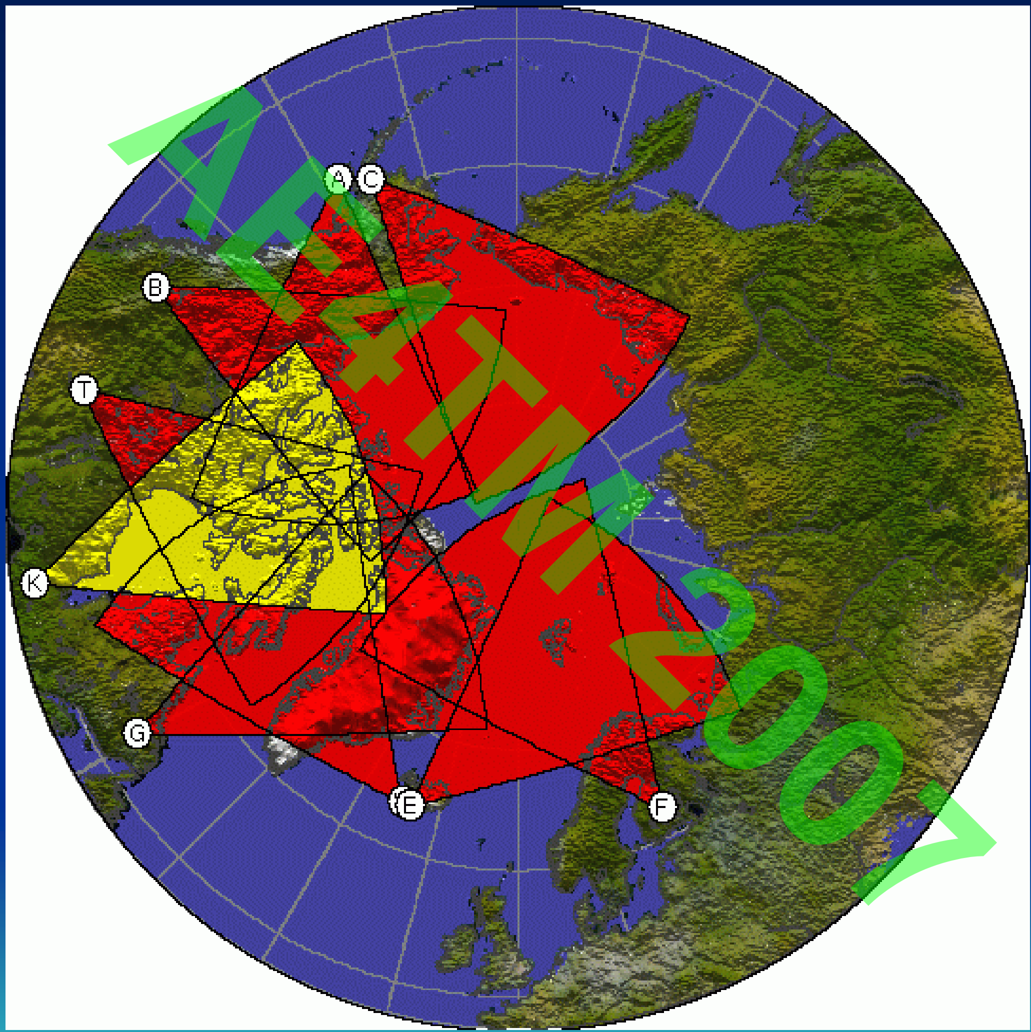
Propagation Times



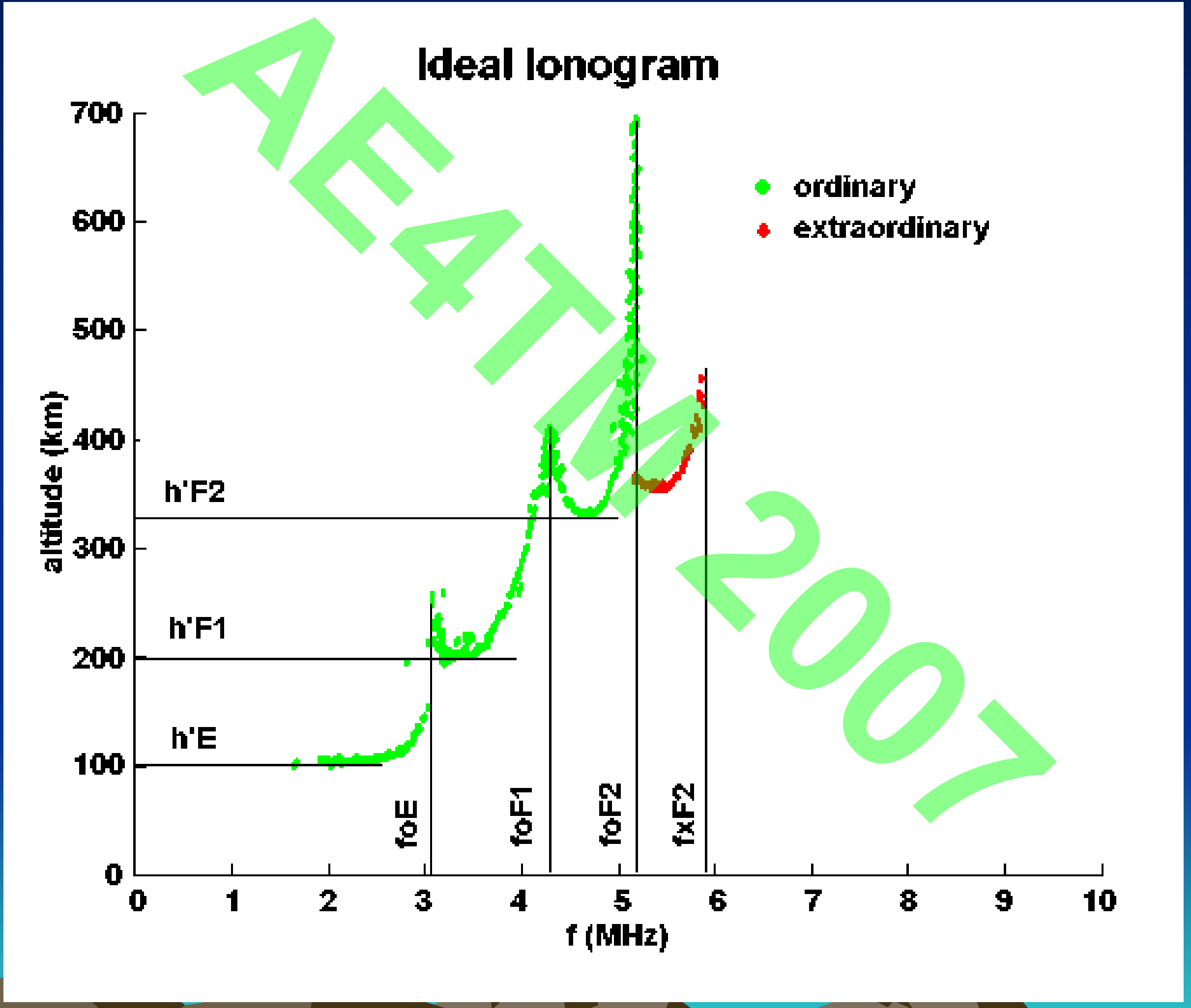
Collaboration with SuperDARN

Photo by Bill Bristow

Kapuskasing SuperDARN Station



Ideal Ionogram



Interpreting Ionograms

$N_{max} = 1.24 \times 10^{10} (f_o^2 \pm f_o f_\omega)$ m^{-3}, where

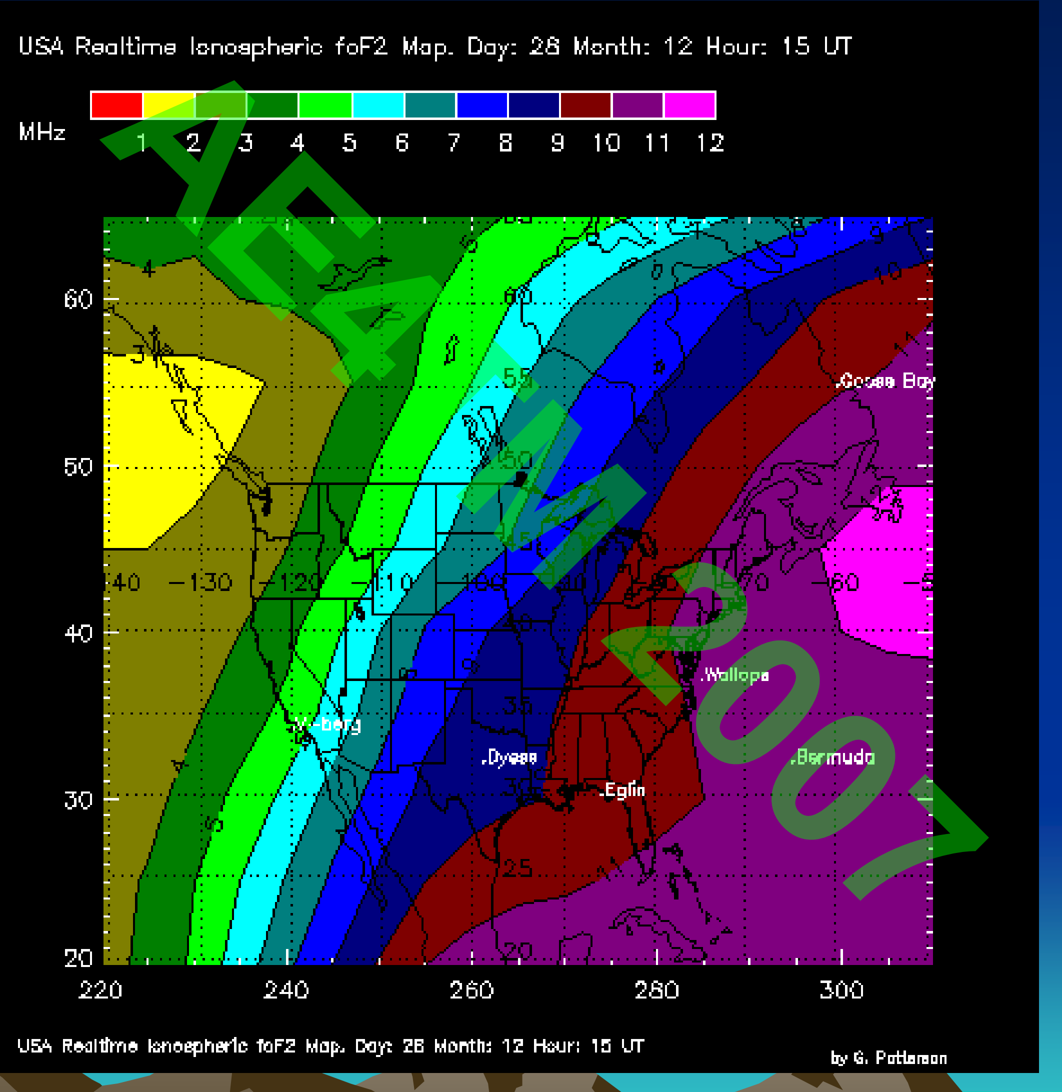
N_{max} is the peak electron density per m^{-3},

f_o is the frequency in MHz, and

f_ω is the plasma frequency ($\sim 10^6$ s^{-1} – 10^7 s^{-1}).

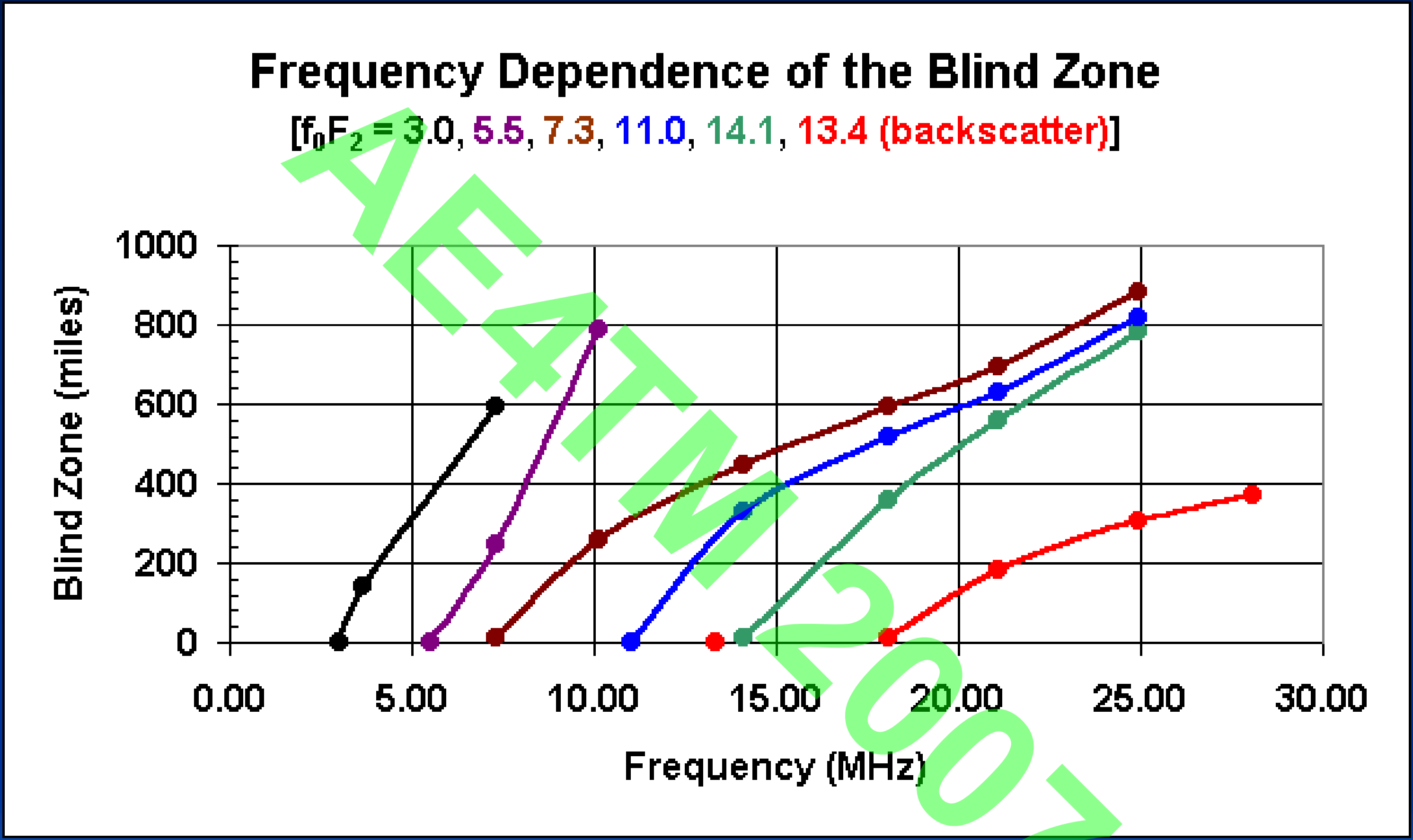
Note: $\pm$ represents the ordinary and extraordinary modes.

f_OF2 Maps



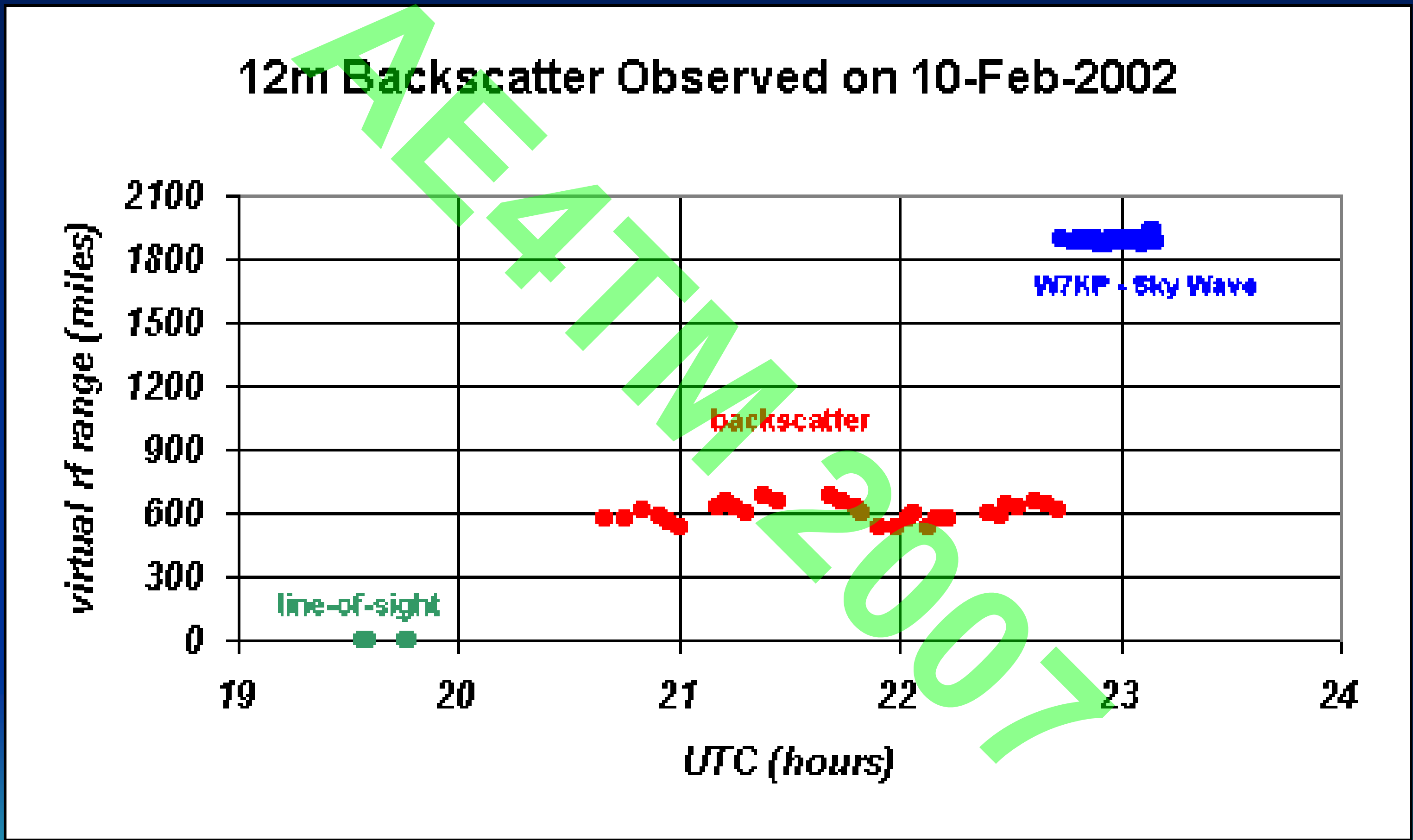
USA Realtime Ionospheric foF2 Map. Day: 28 Month: 12 Hour: 15 UT
MHz
1 2 3 4 5 6 7 8 9 10 11 12
60
50
40
30
20
220
240
260
280
300
-140 -130 -120 -110 -100 -90 -80 -70 -60
Goose Bay
Wallops
V-berg
Dyess
Bermuda
Eglin
USA Realtime Ionospheric foF2 Map. Day: 28 Month: 12 Hour: 15 UT
by G. Patterson

Frequency Dependence of HF Blind Zone

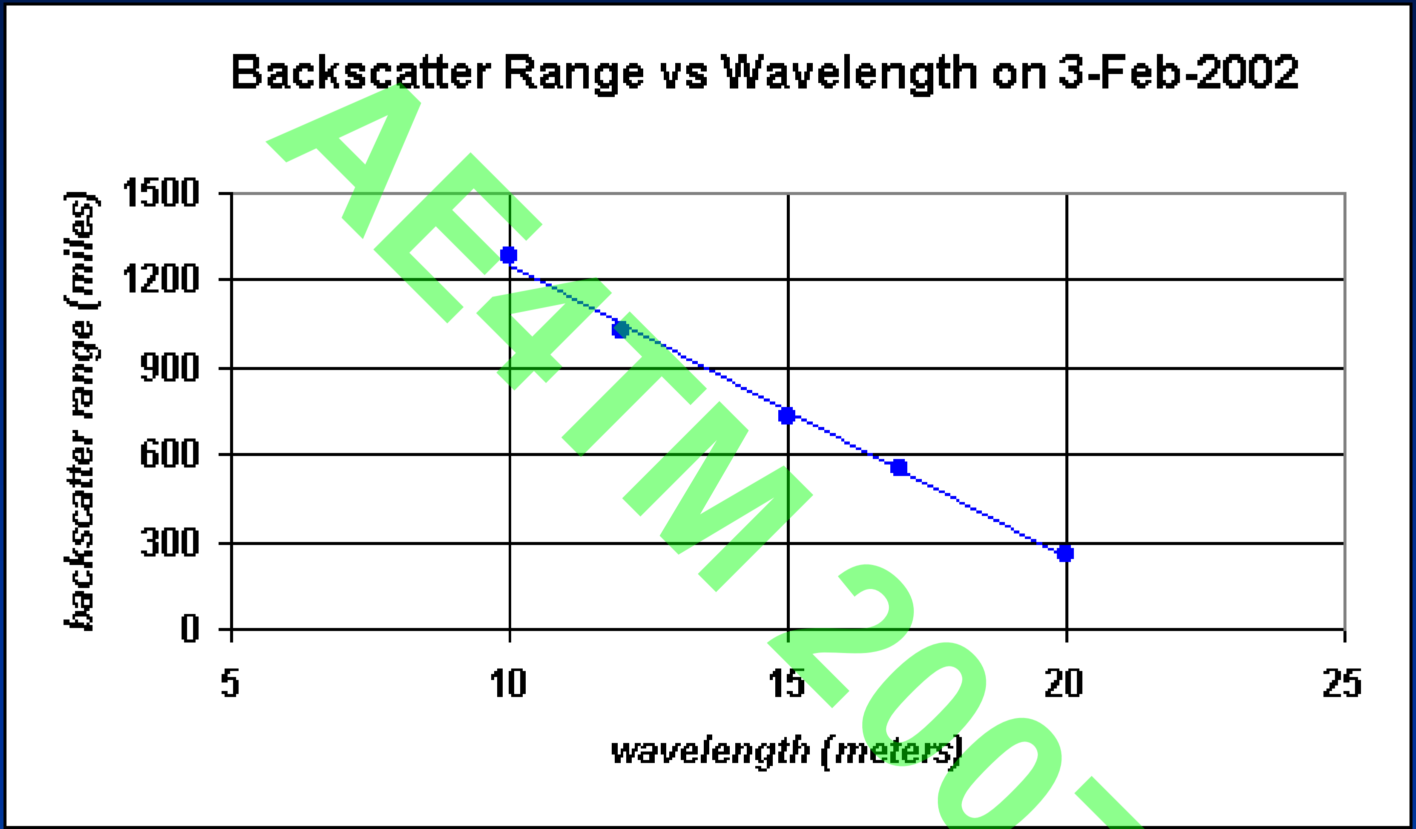


Blind Zone (mi) ~ 730 LN [f / foF2] +78

HF Backscatter (“*long skip*”)

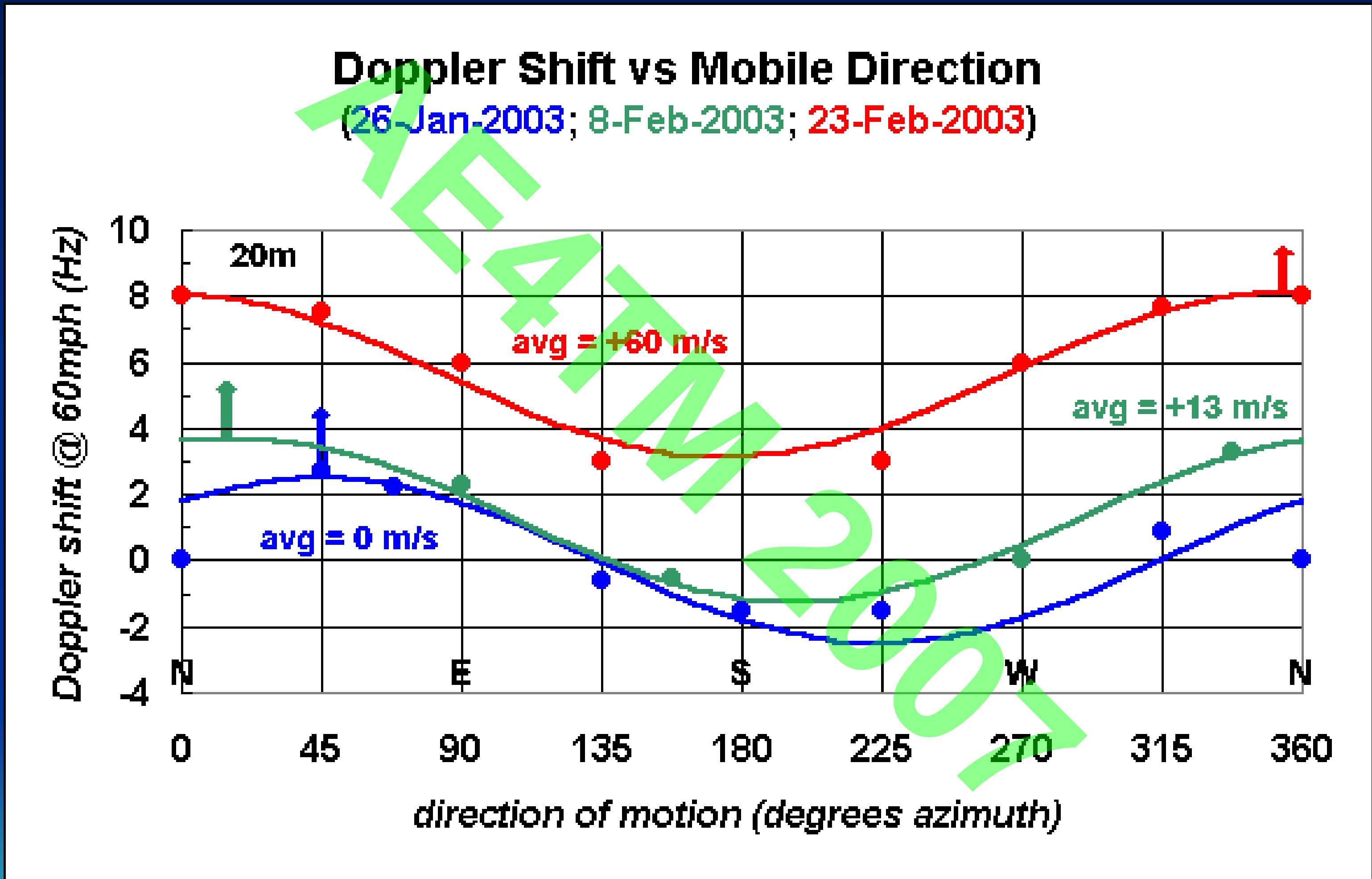


Backscatter Range vs Wavelength

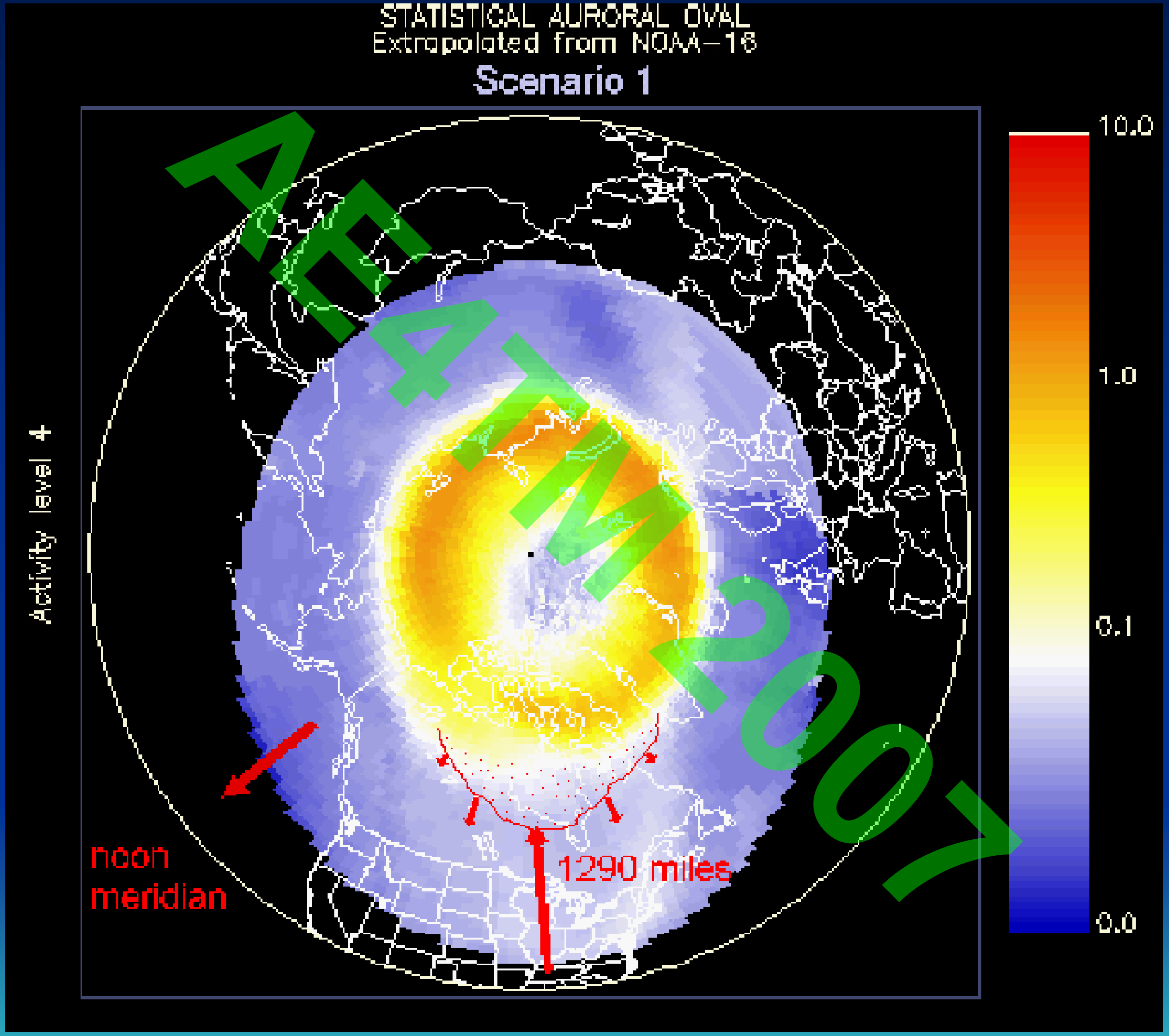


$N_{max} \sim 1.24 \times 10^{10} (f_o^2)\ m^{-3}$

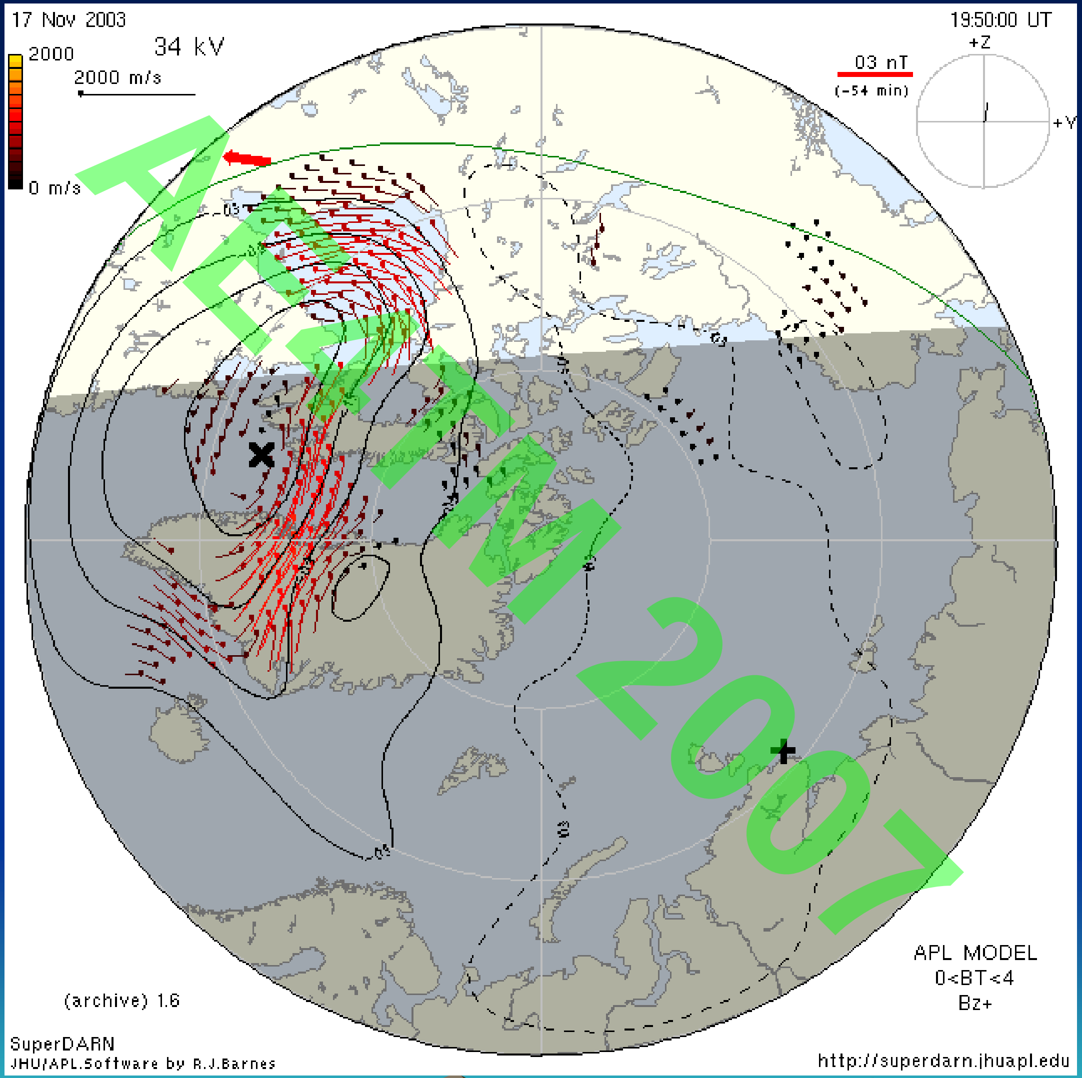
Direction to Backscatter Source



Auroral Oval and Backscatter



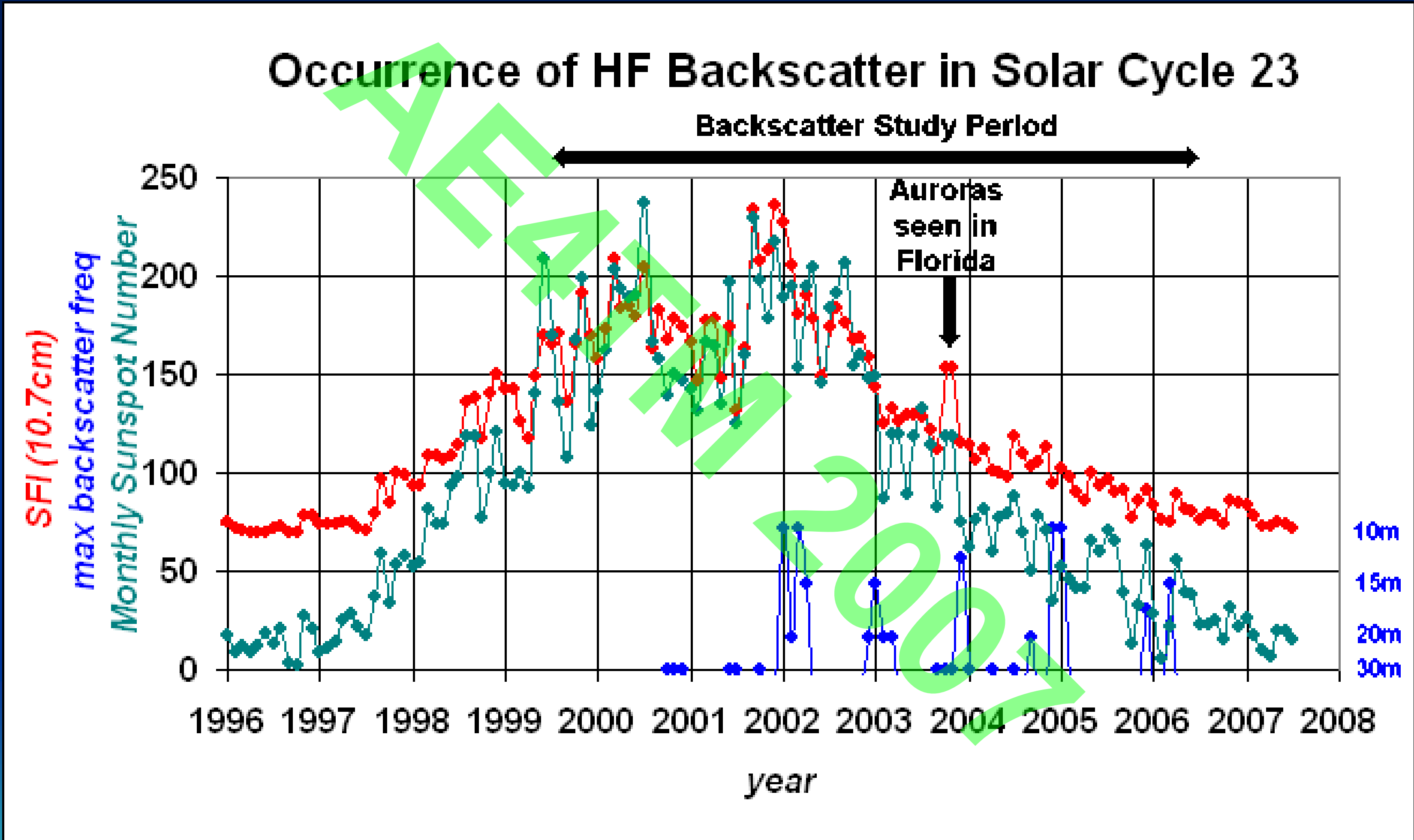
Source of Backscatter Ion Clouds



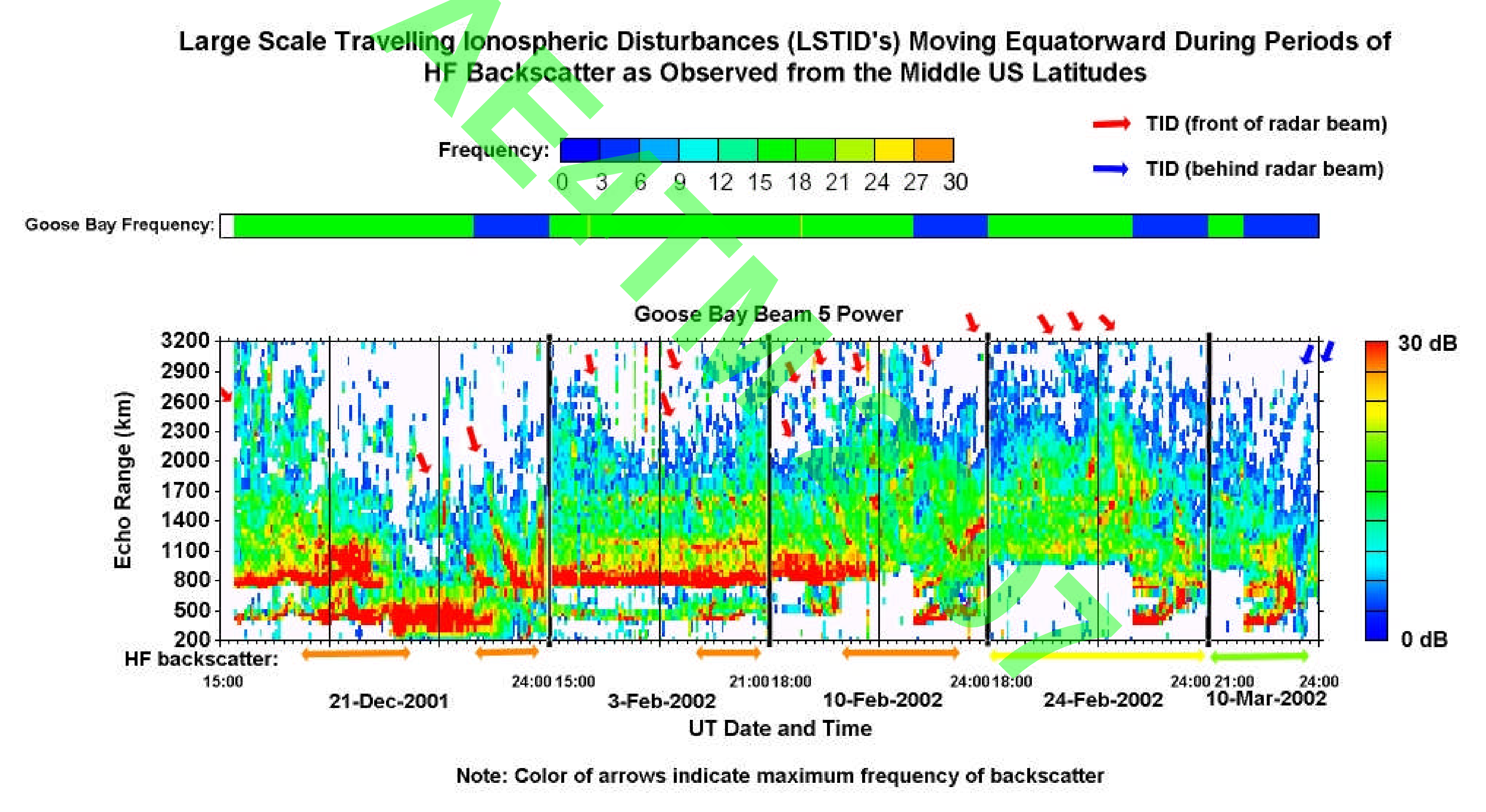
Animation: http://ecjones.org/_backscat/Nov17_2003_bksct.gif

Auroral Images (Fairbanks AK)

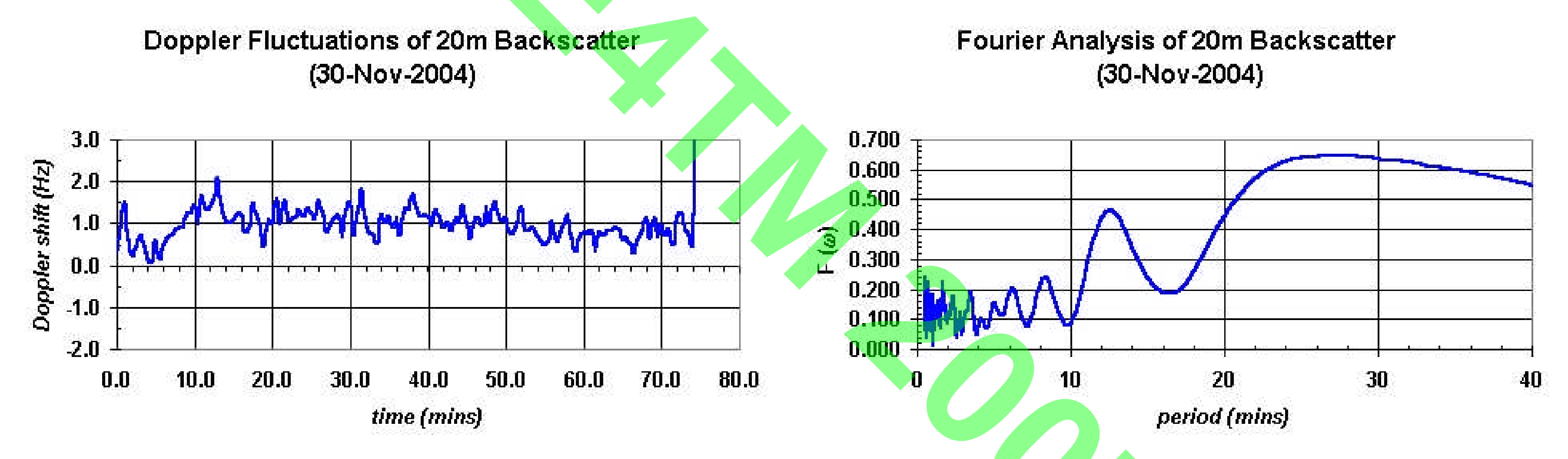
Seasonal Pattern for Backscatter



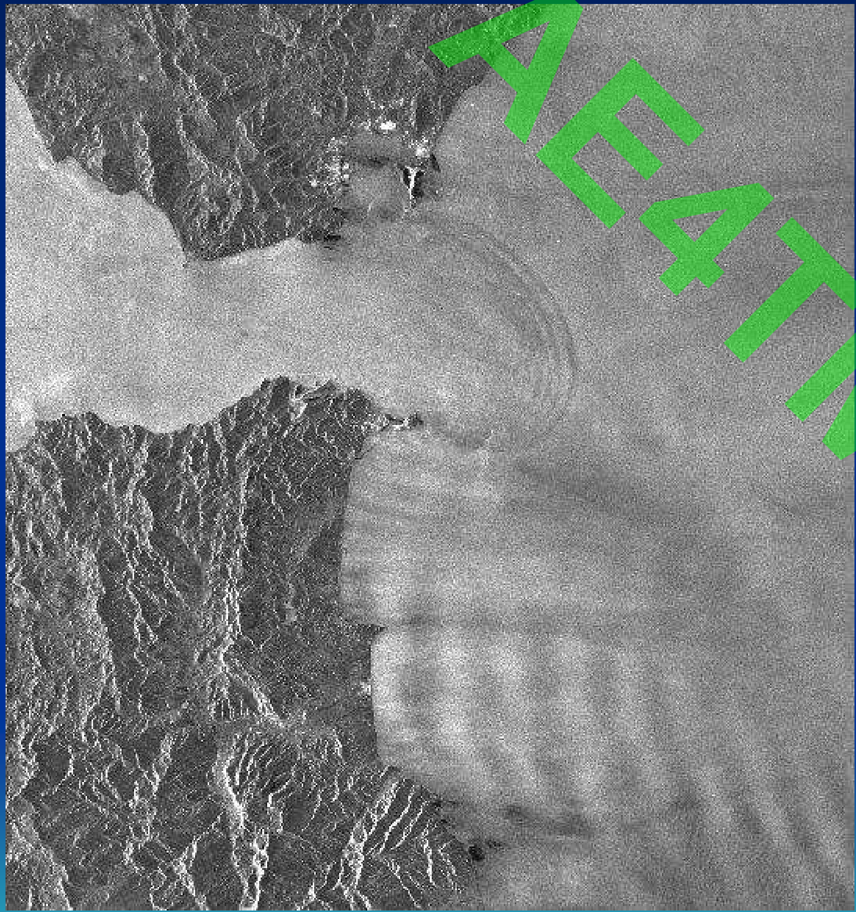
Backscatter with SuperDARN

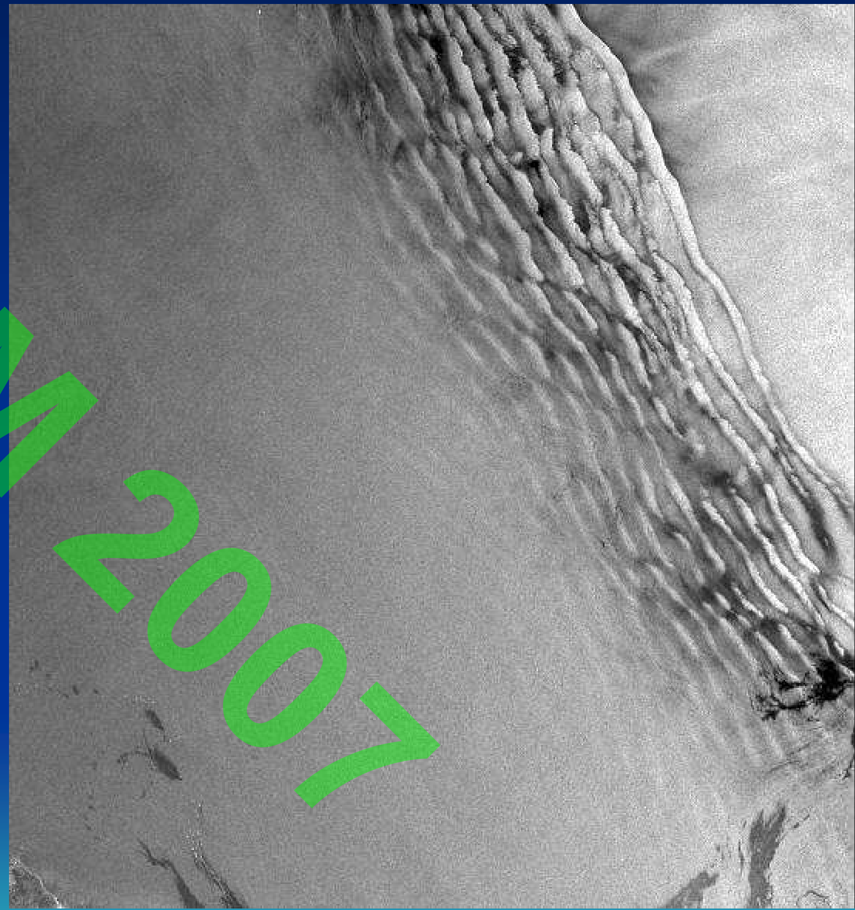


Backscatter and TID's (Travelling Ionospheric Disturbances)



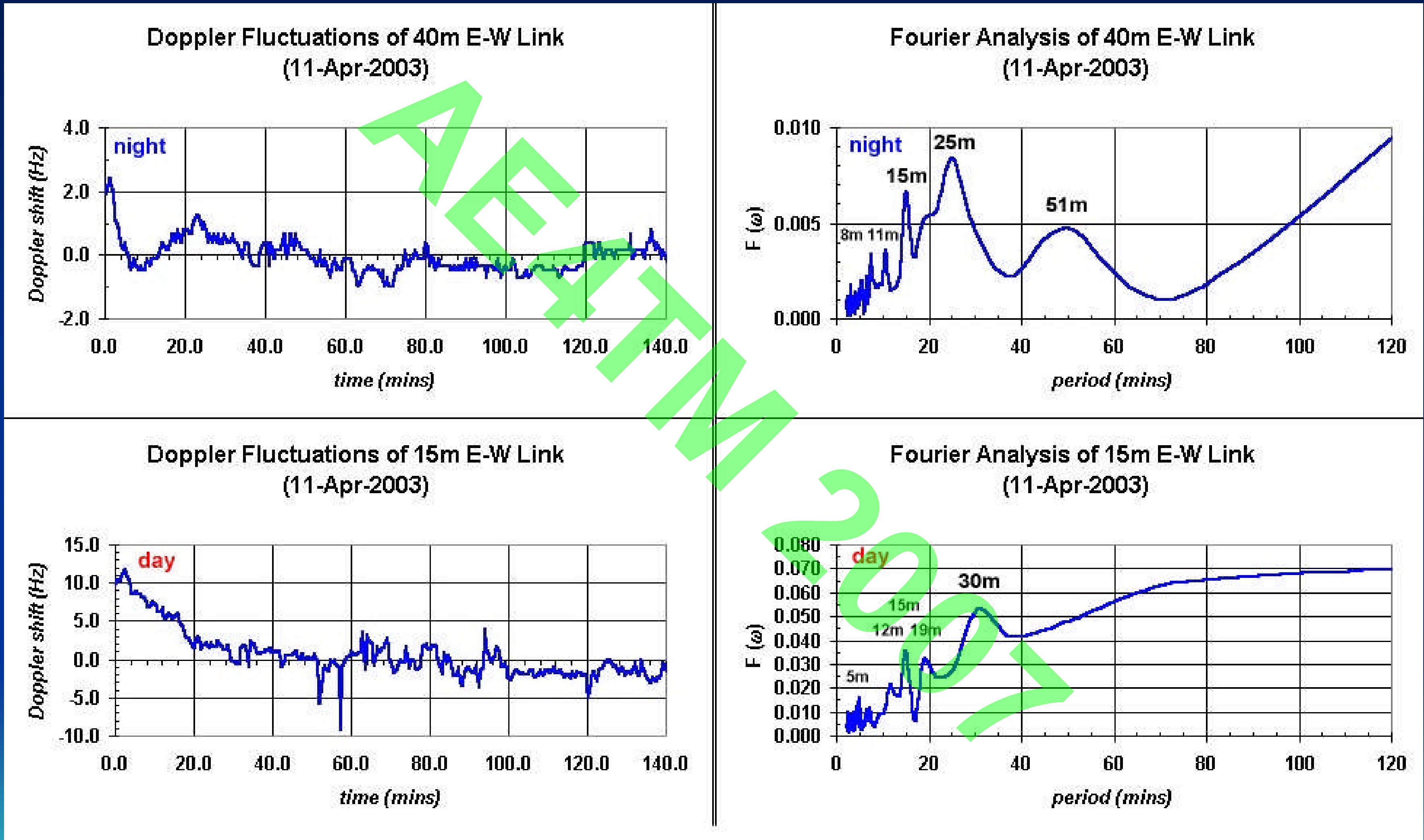
Atmospheric Gravity Waves (AGW)



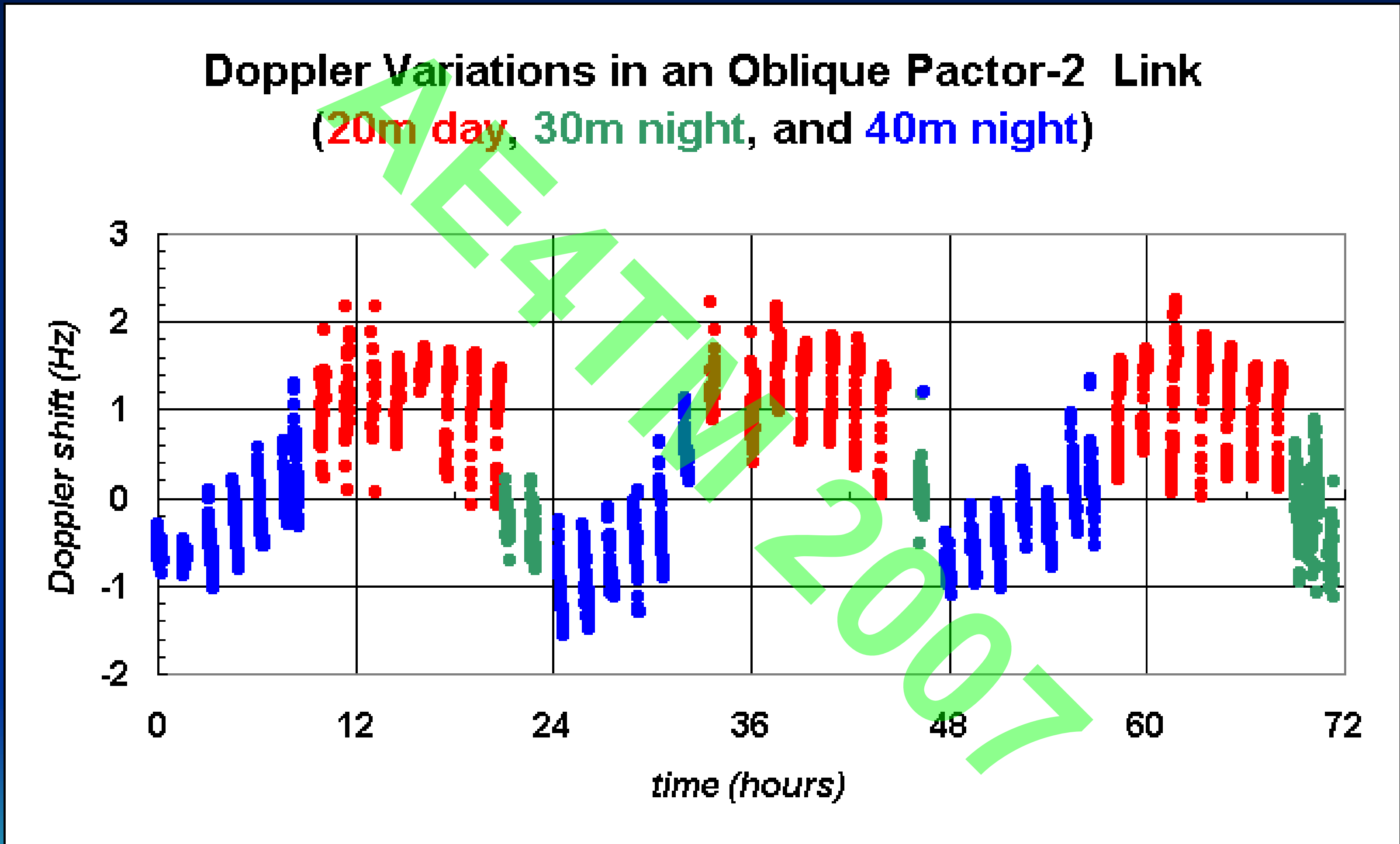


HF Doppler Study

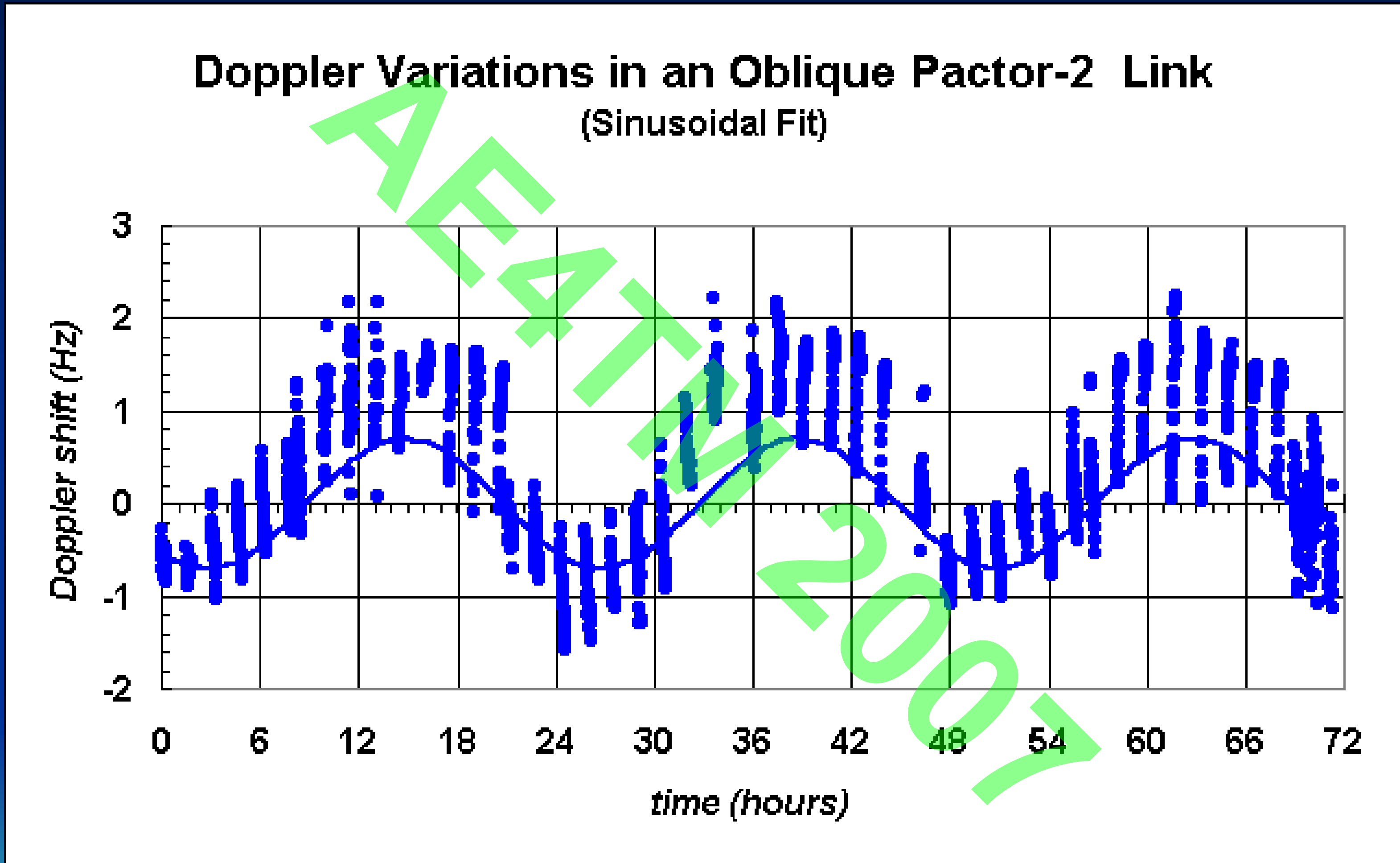
HF Doppler Fluctuations



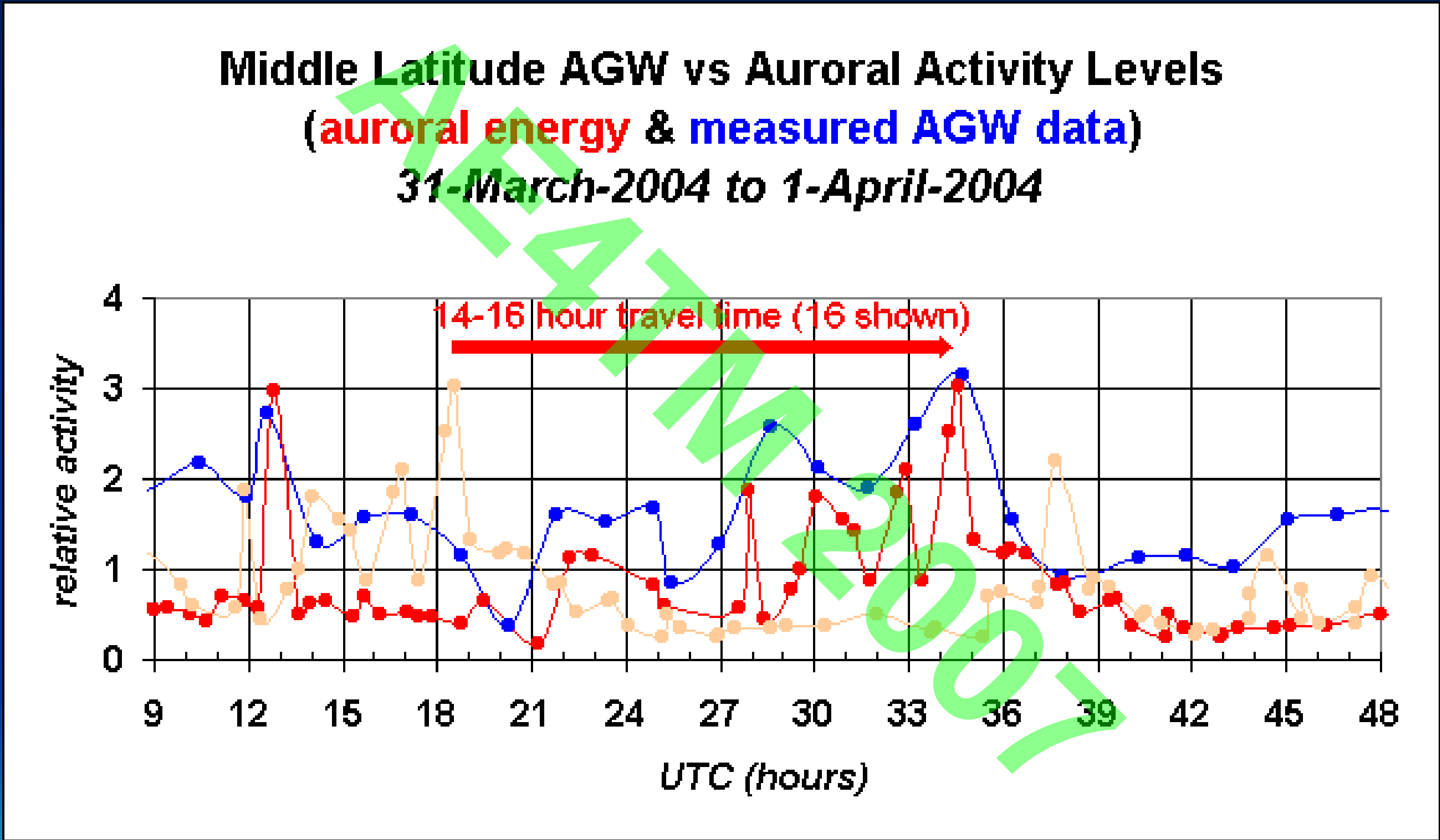
Doppler Shifts in Oblique Links



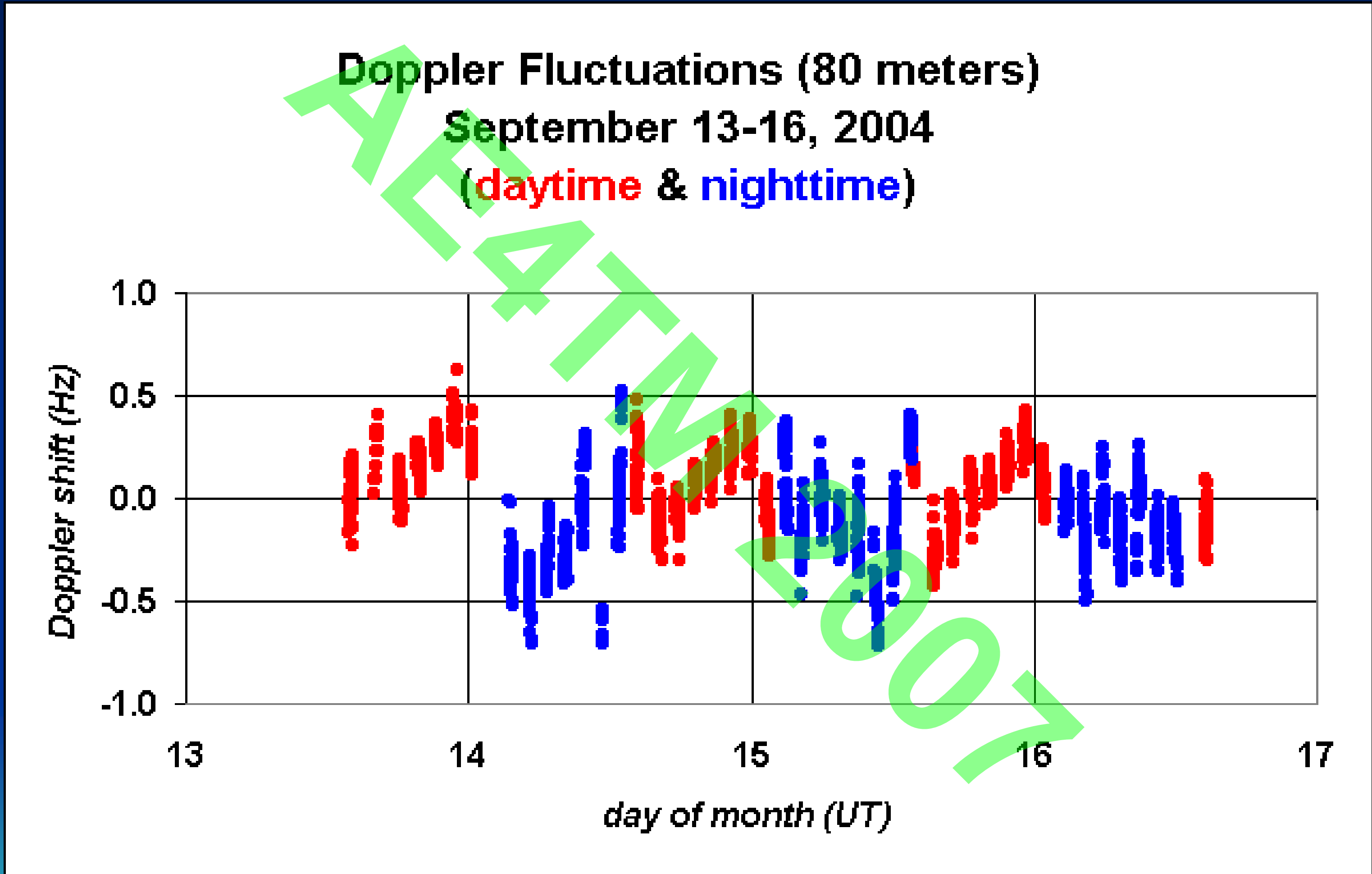
Determining the 0 Hz Doppler Shift



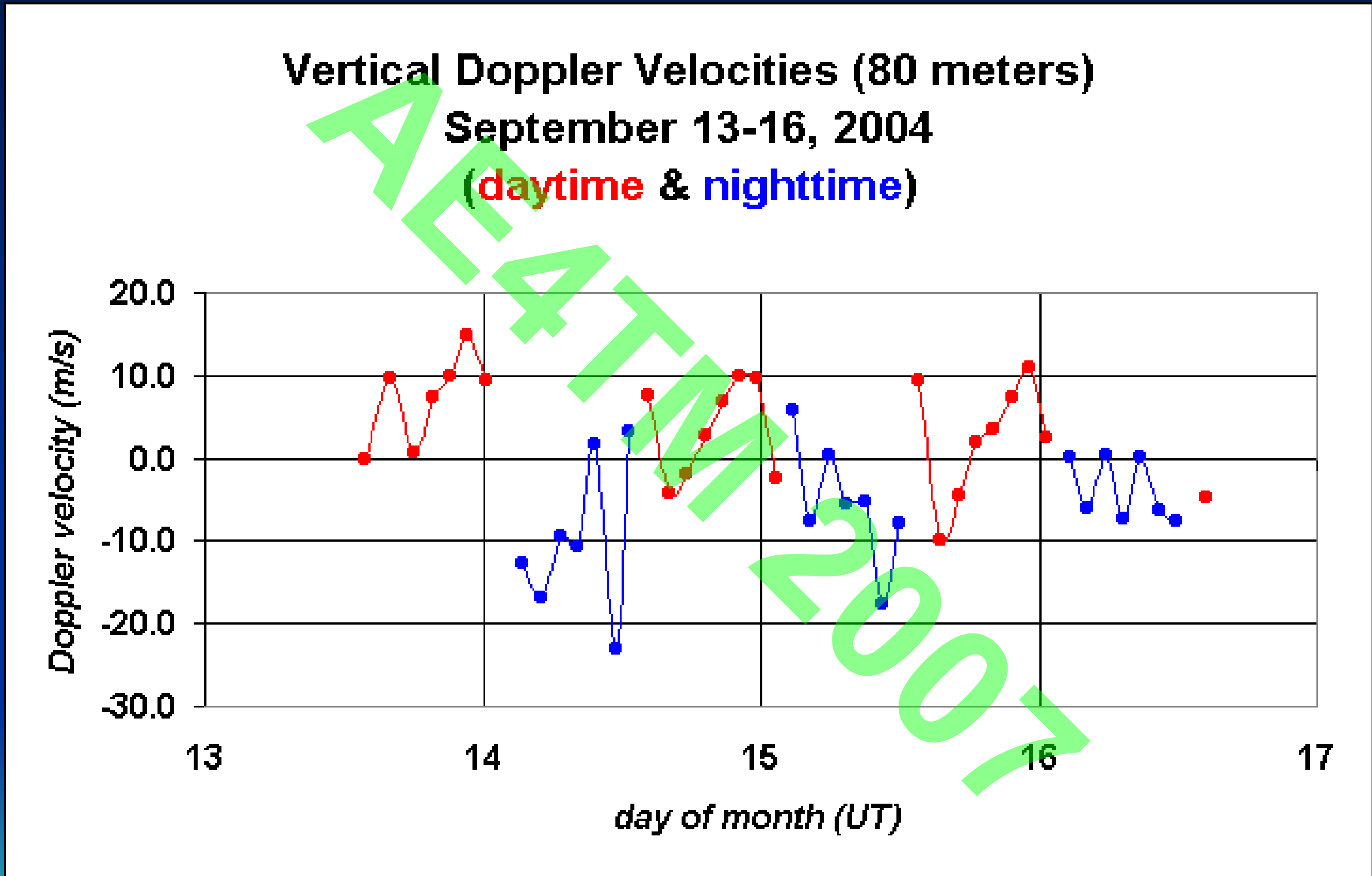
Determining the TID Velocity



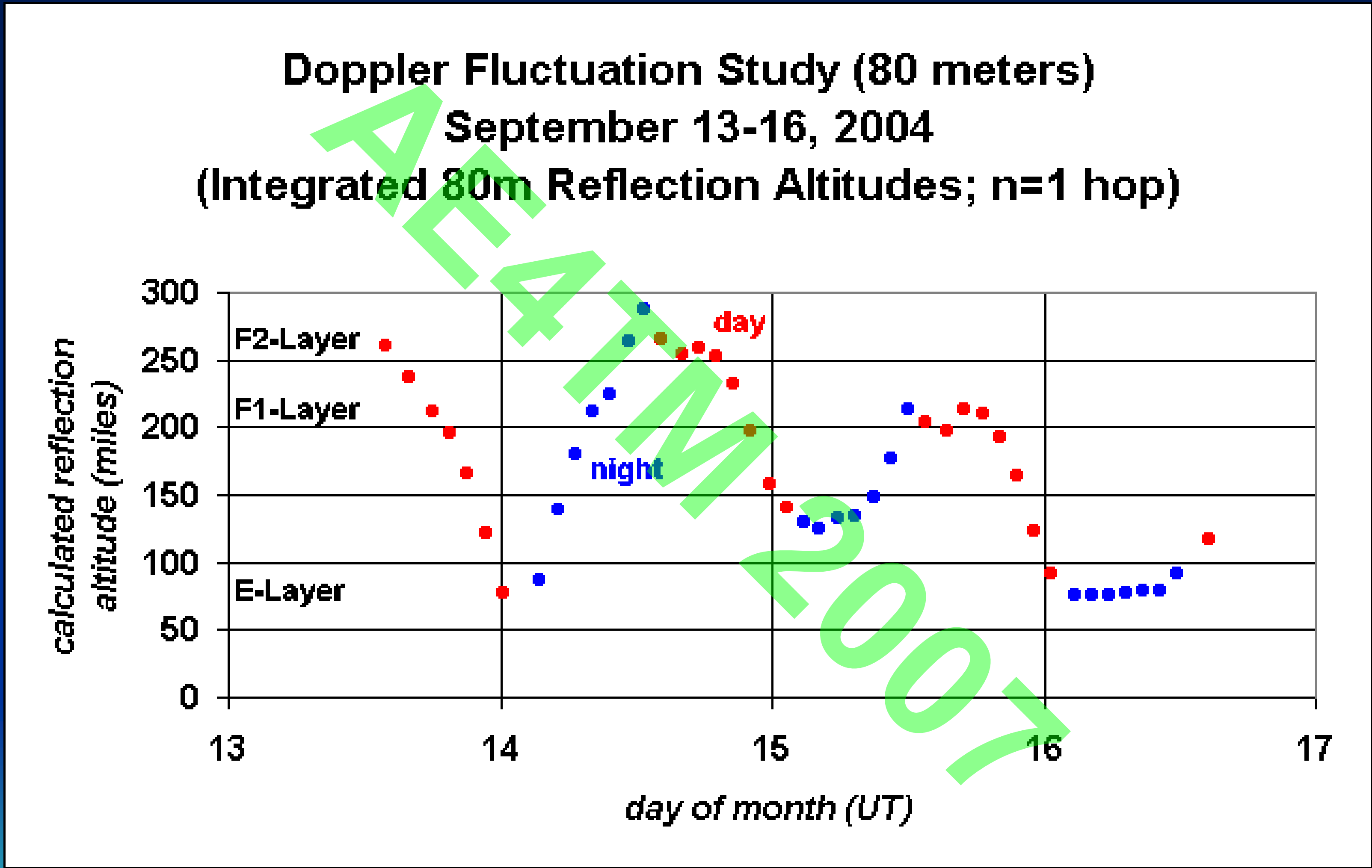
Doppler Shifts on 80m



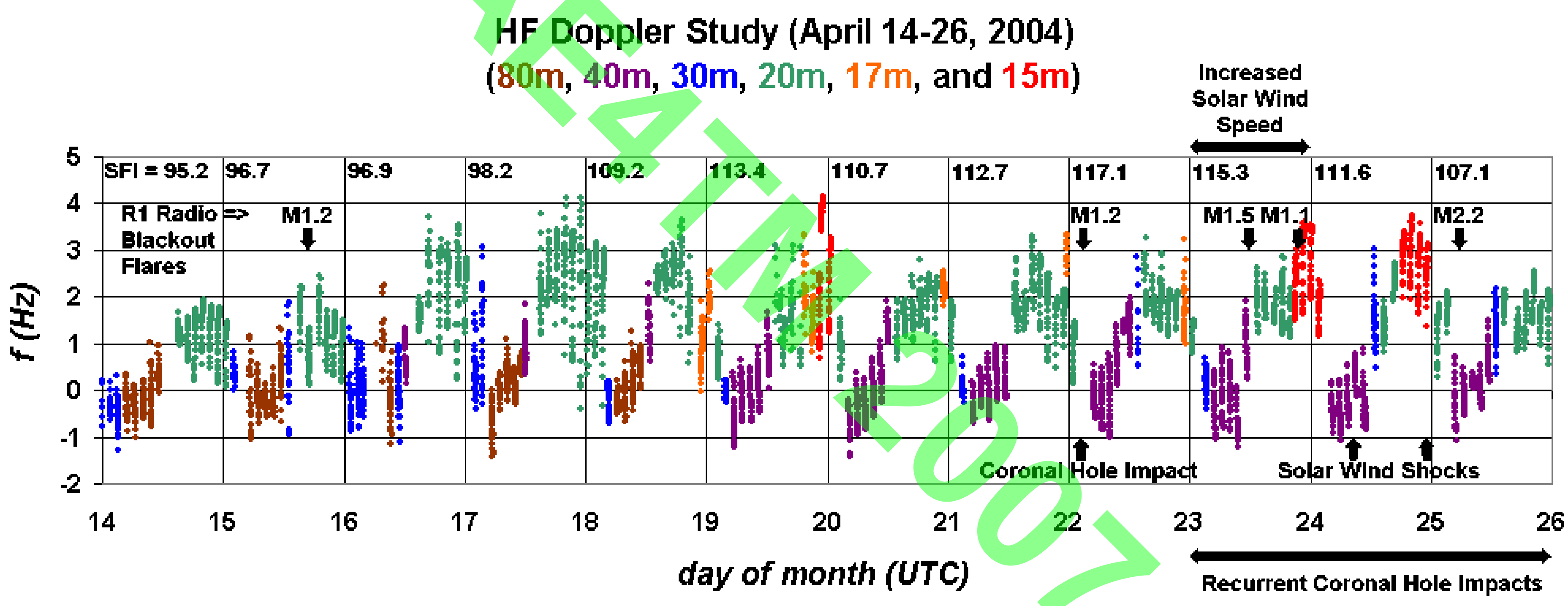
Calculated Vertical Velocities on 80m



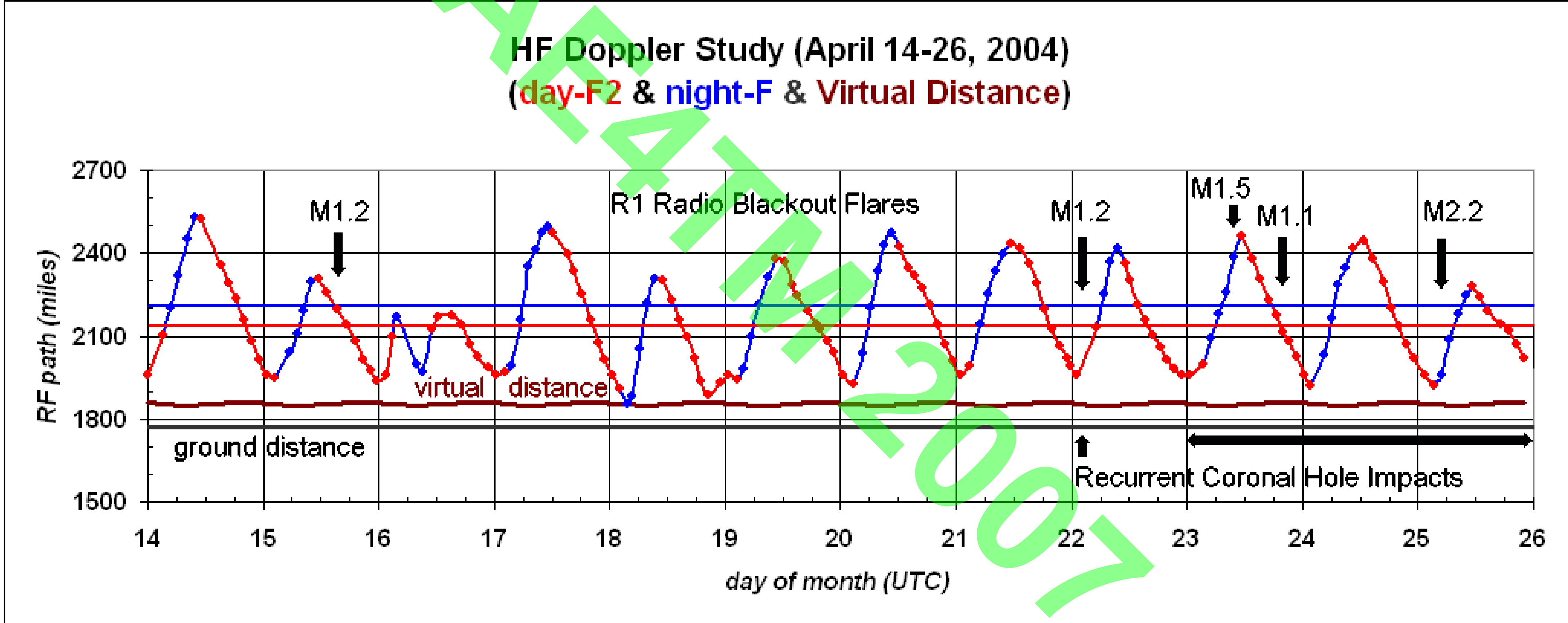
Integrated Reflection Altitudes on 80m



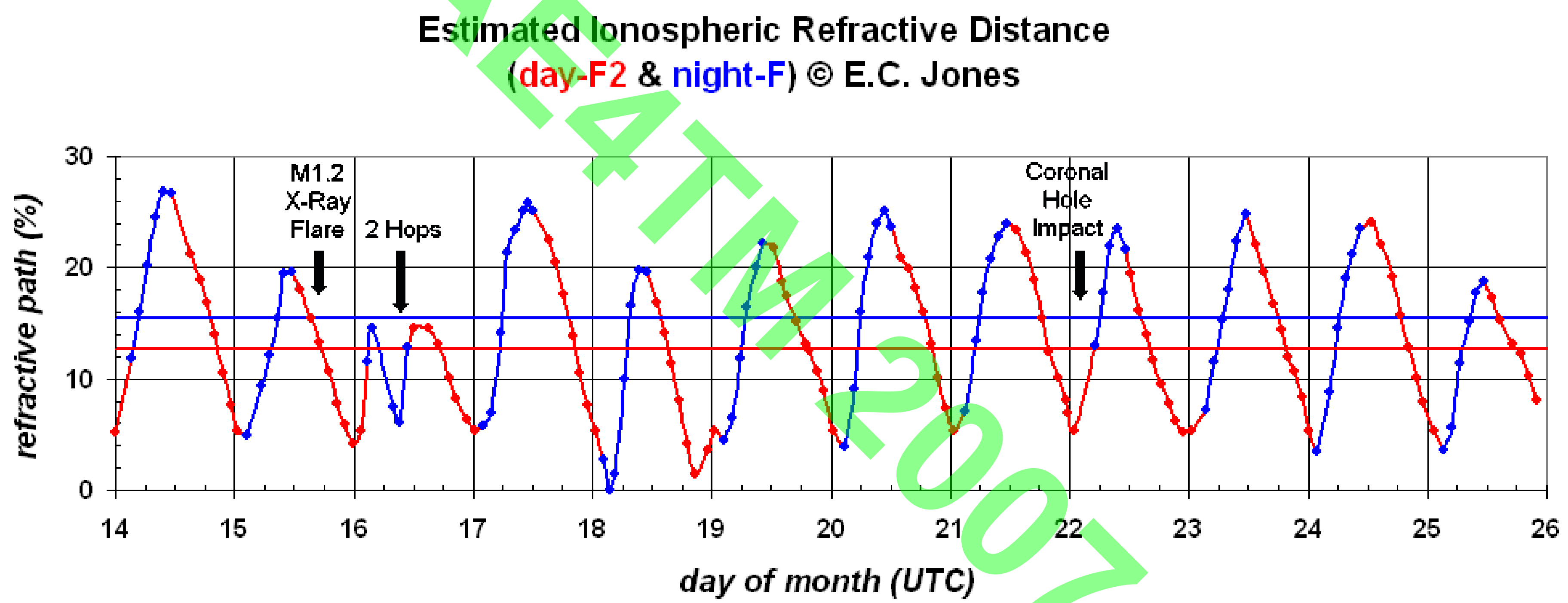
Doppler Shift Variation over a 12 Day Period (April 14-26, 2004)



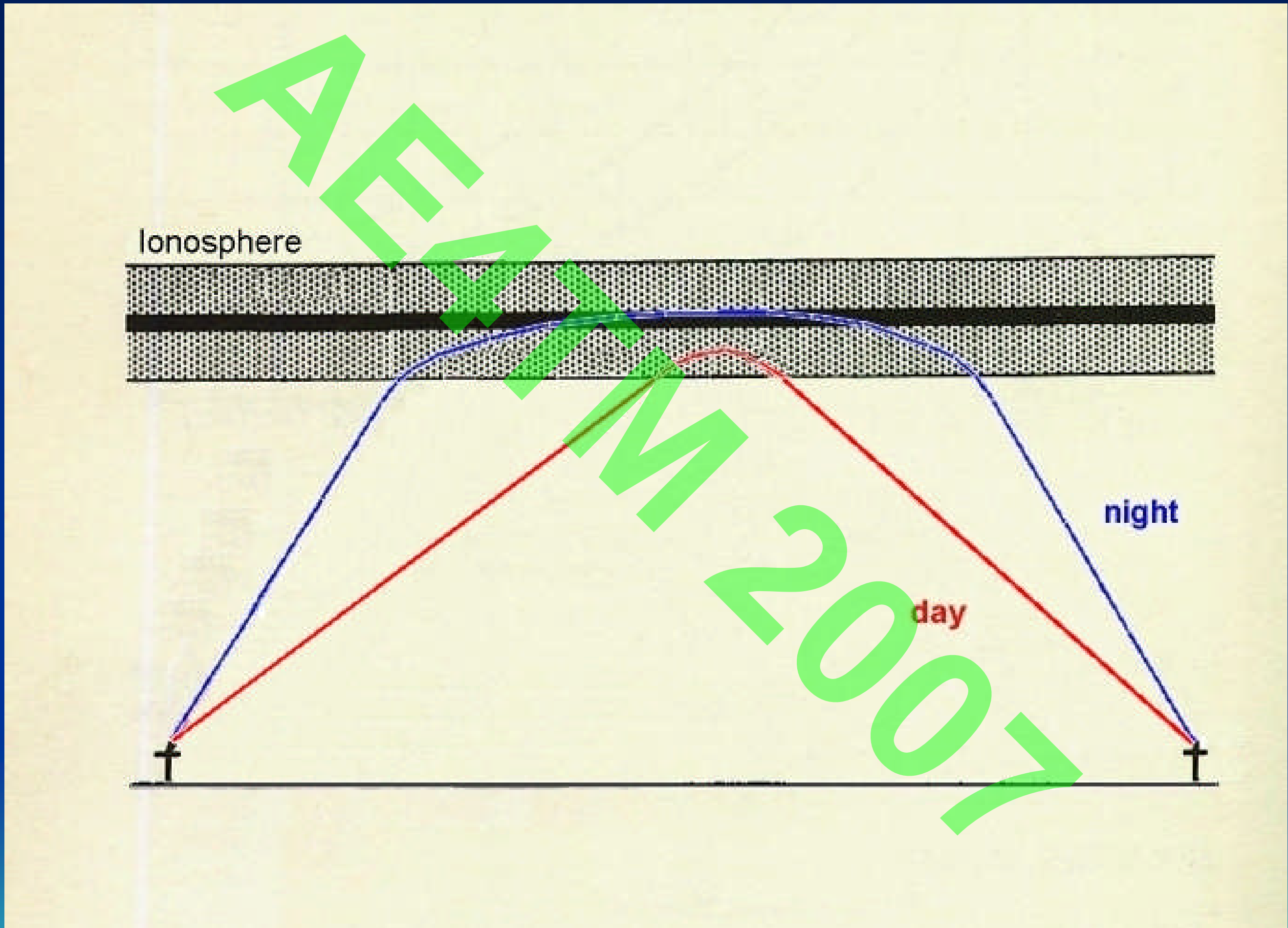
Integrated RF Paths over a 12 Day Period (April 14-26, 2004)



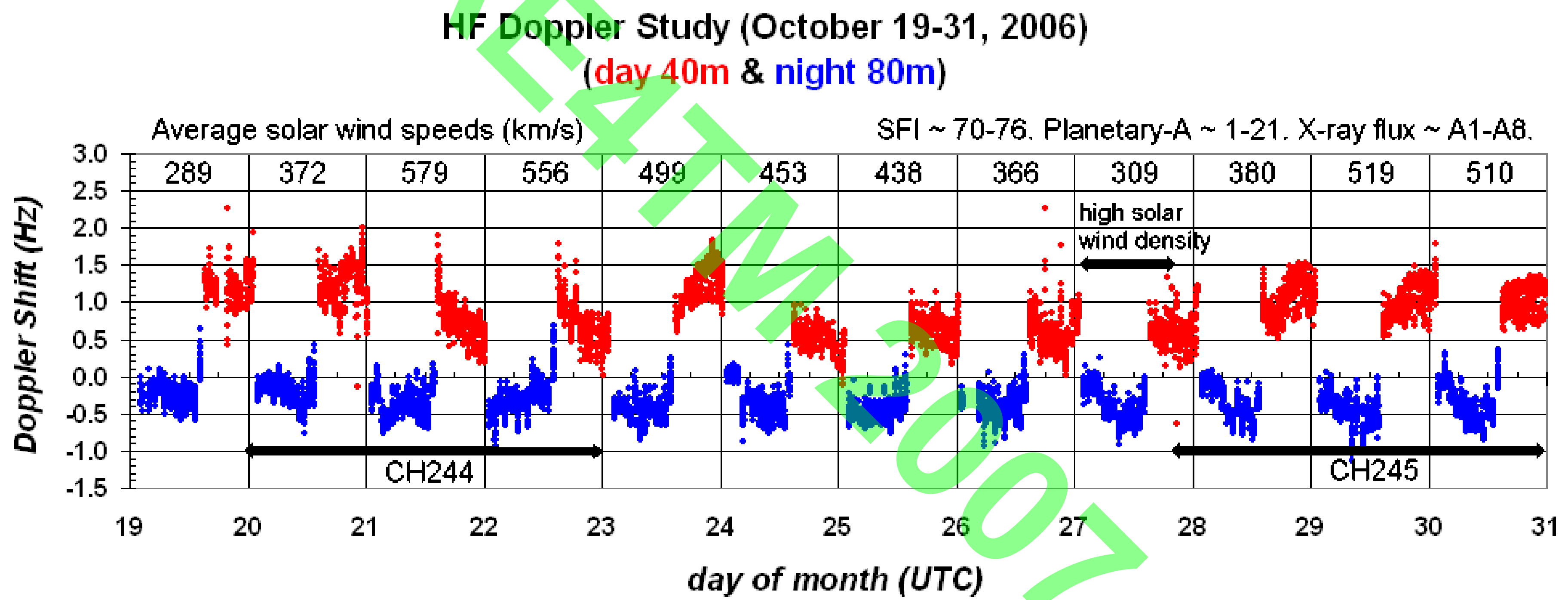
Ionosphere Refraction Distance (April 14-26, 2004)



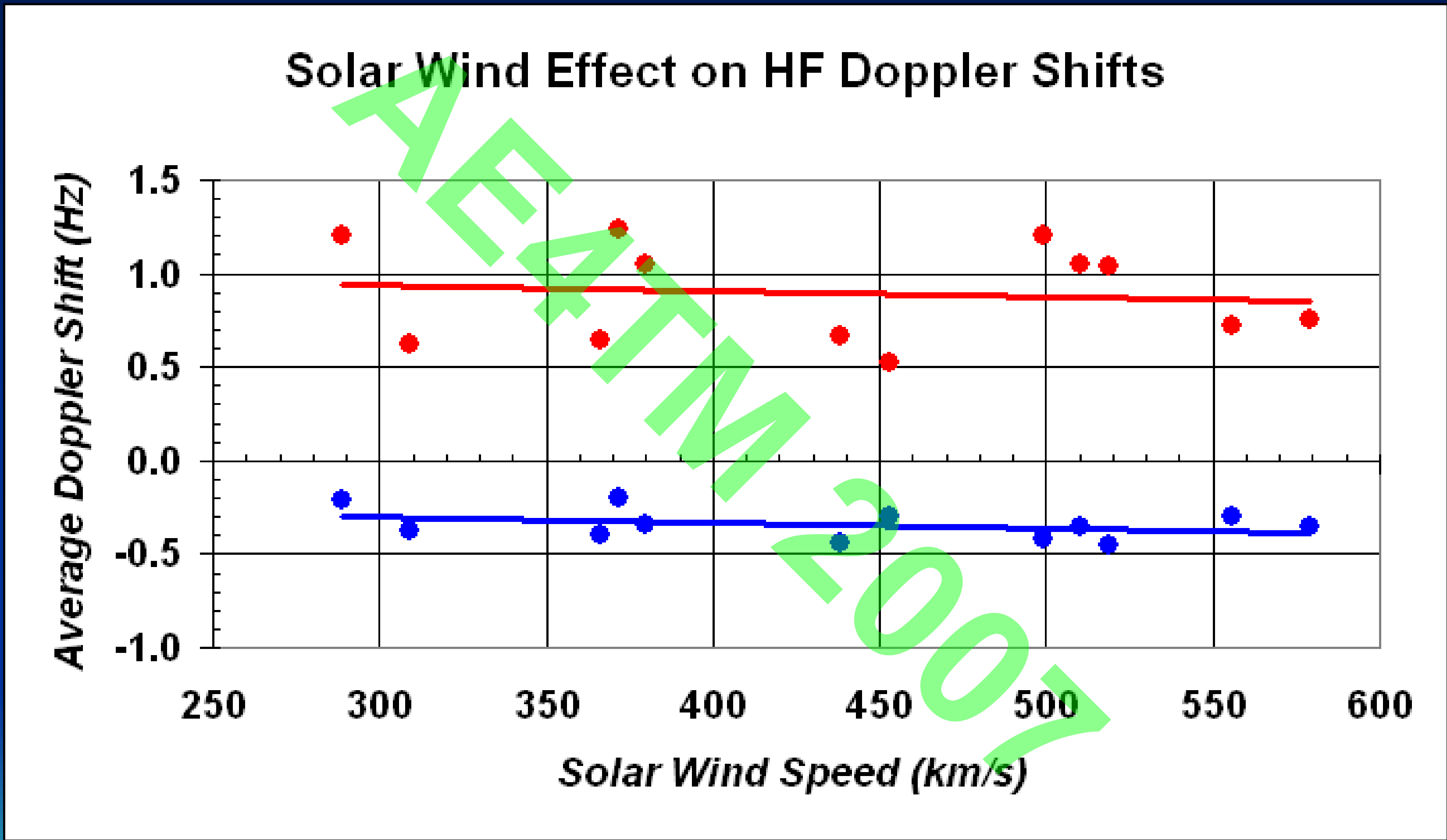
HF Ionospheric Refraction



Doppler Shift Variation over a 12 Day Period (October 19-31, 2006)



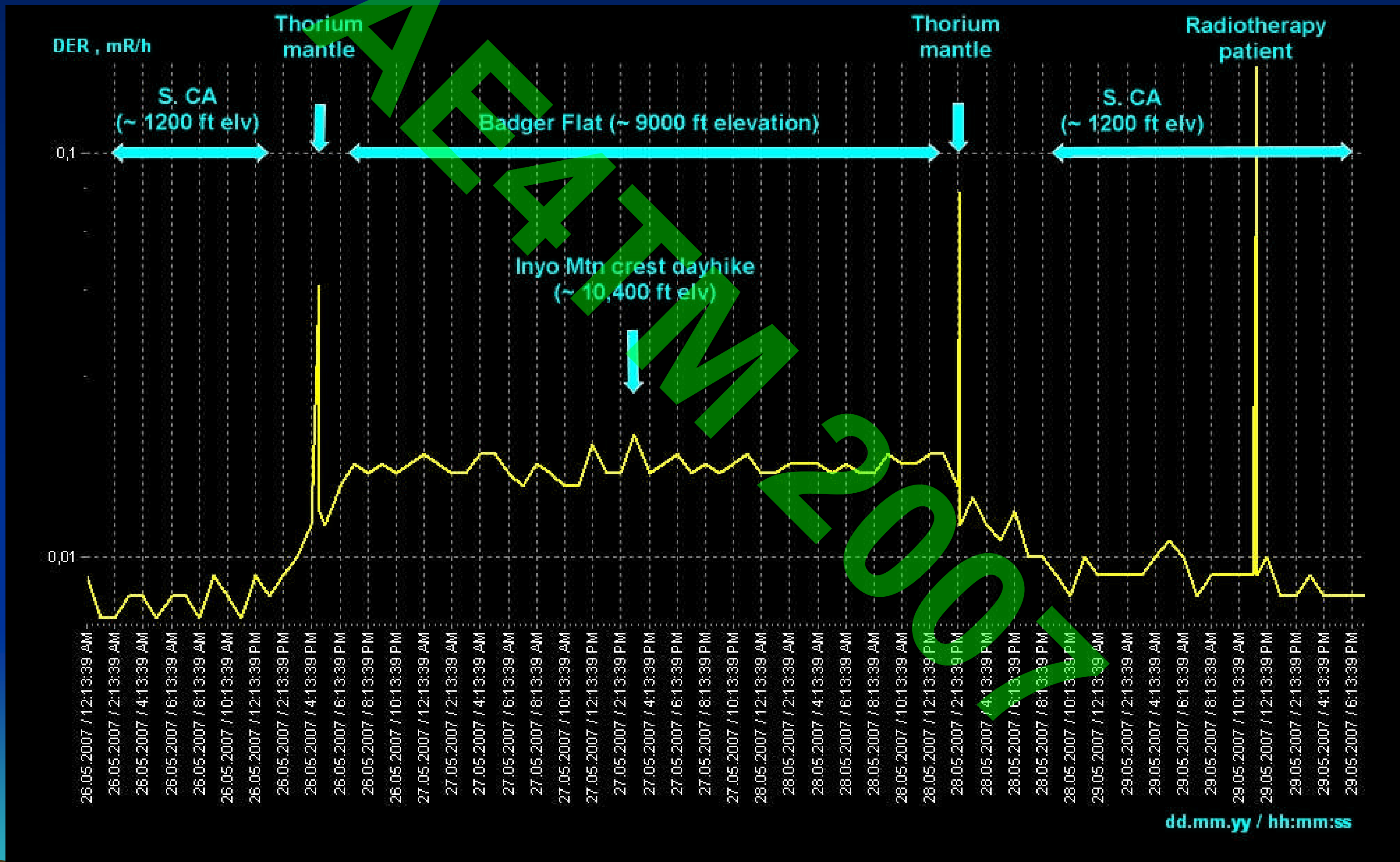
Solar Wind Effect on HF Doppler Shifts



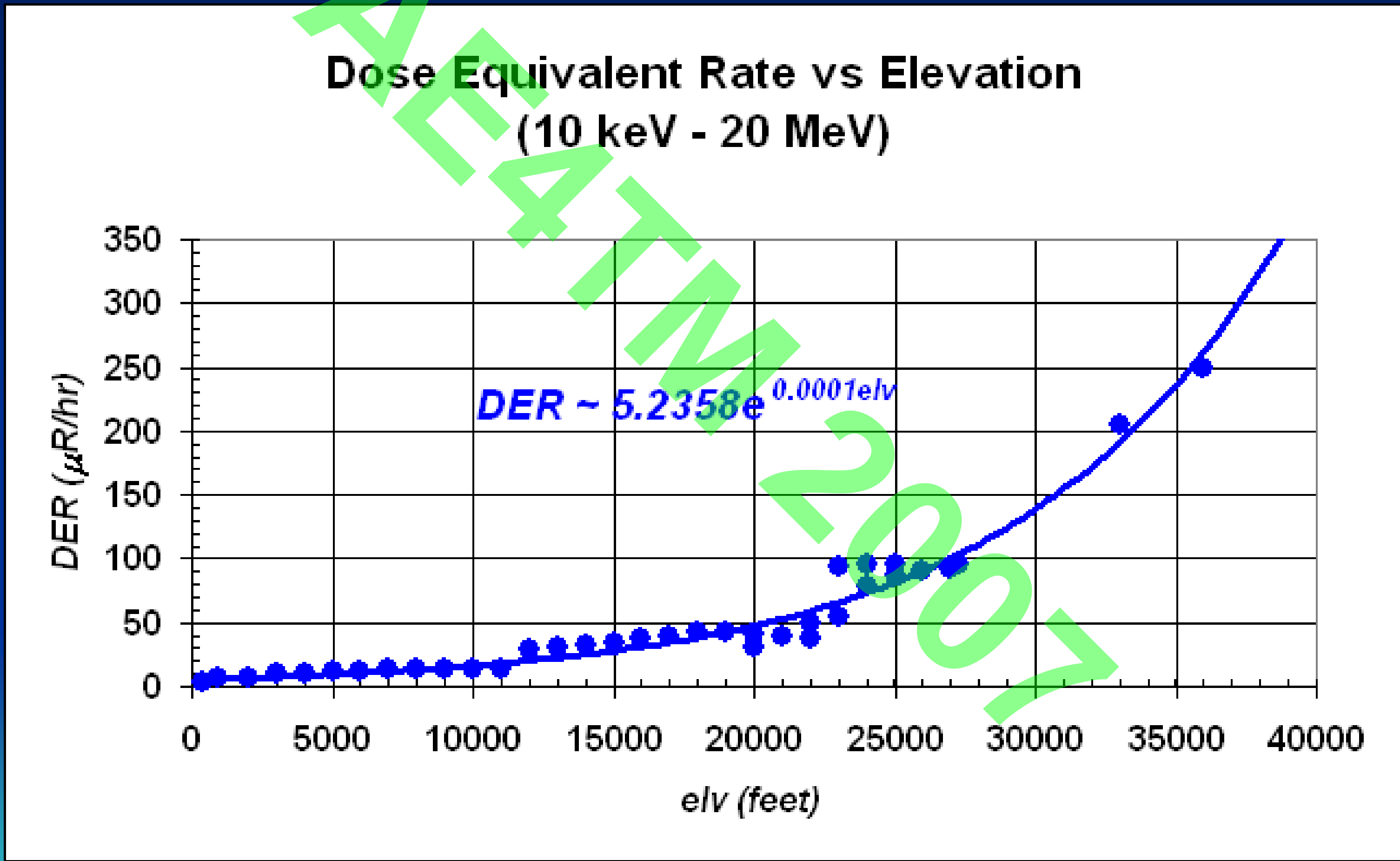
Introducing Radiation Detectors to Study

- PM1621A: GM Tube, 10 KeV - 20.0 MeV, and 10s response time
- PM1703MA: CsI(Tl), 33 KeV - 3.0 MeV, and 0.25s response time

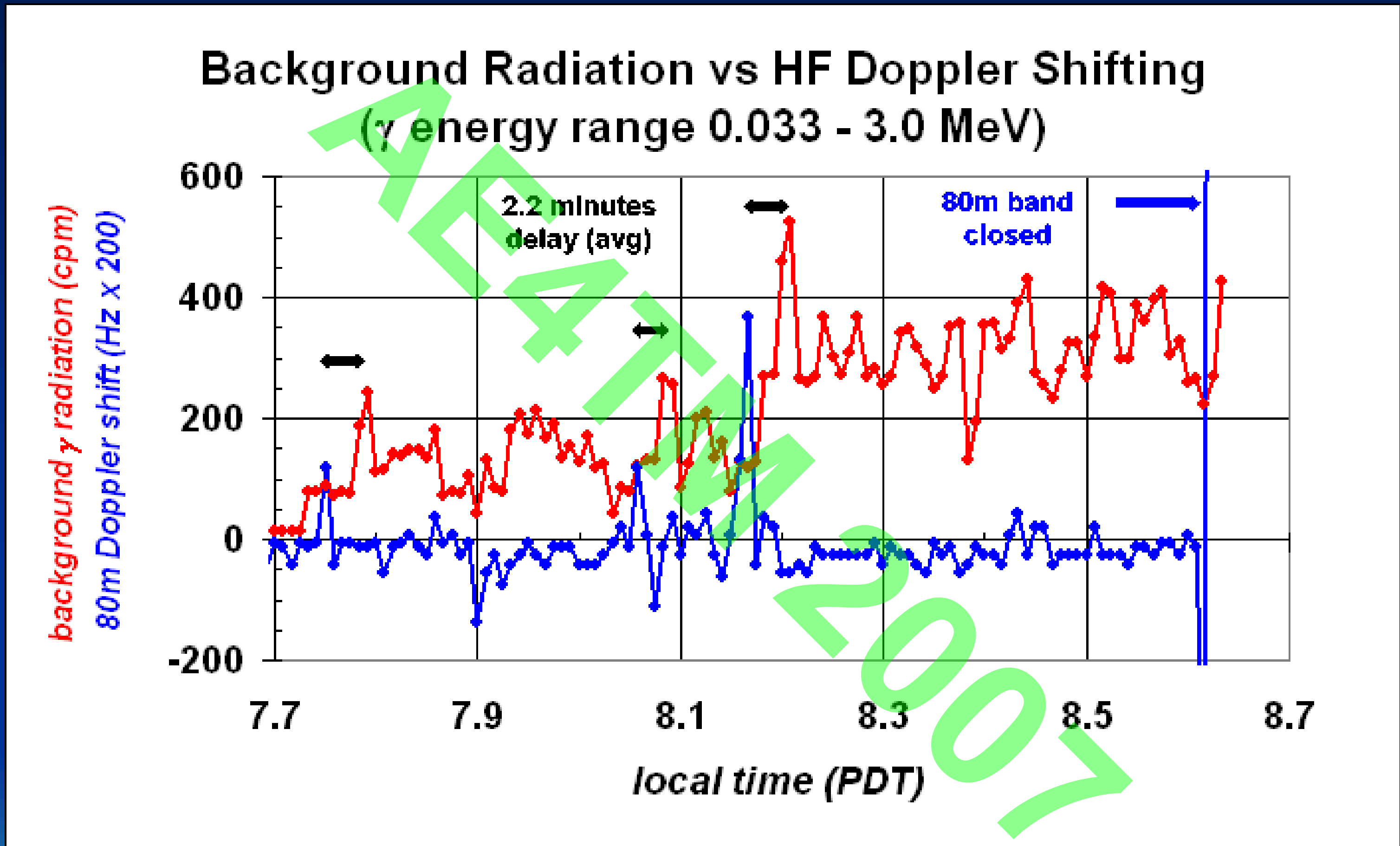
Effect of Elevation on Background Radiation (10keV-20MeV)



Effect of Altitude on Background Radiation (Lat 35º)

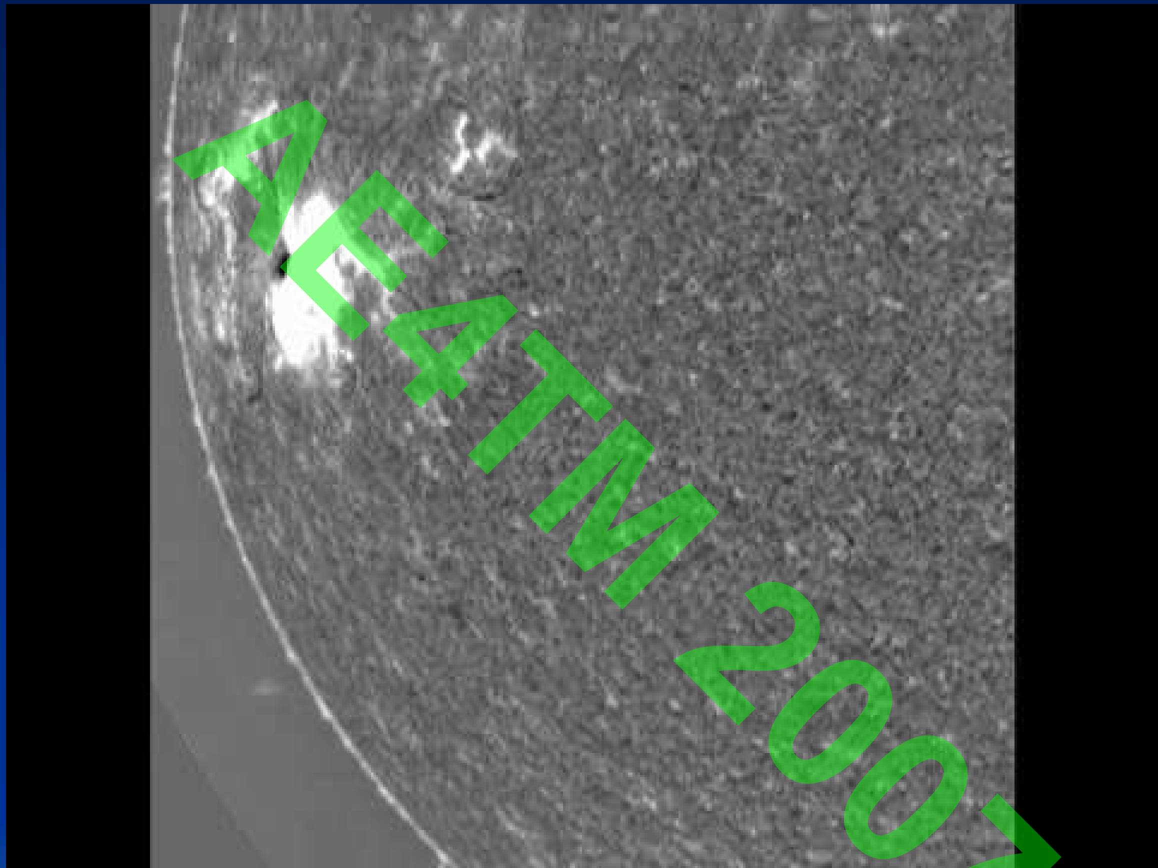


Solar Wind Interaction with the Ionosphere



At 400km/s, travel distance ~50 km or ~30 mi

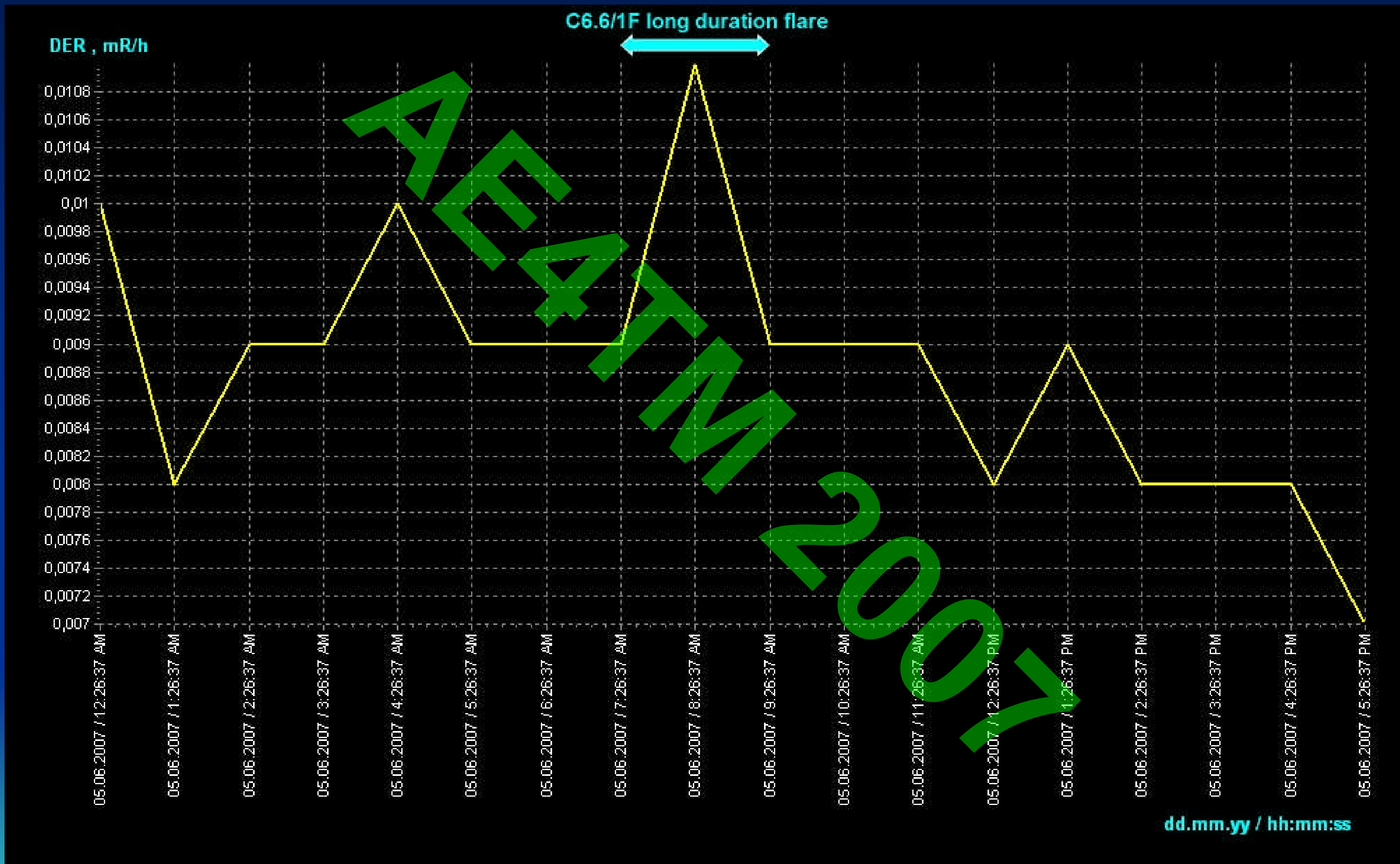
Moreton Wave 5-Jul-2006 (X6.5)



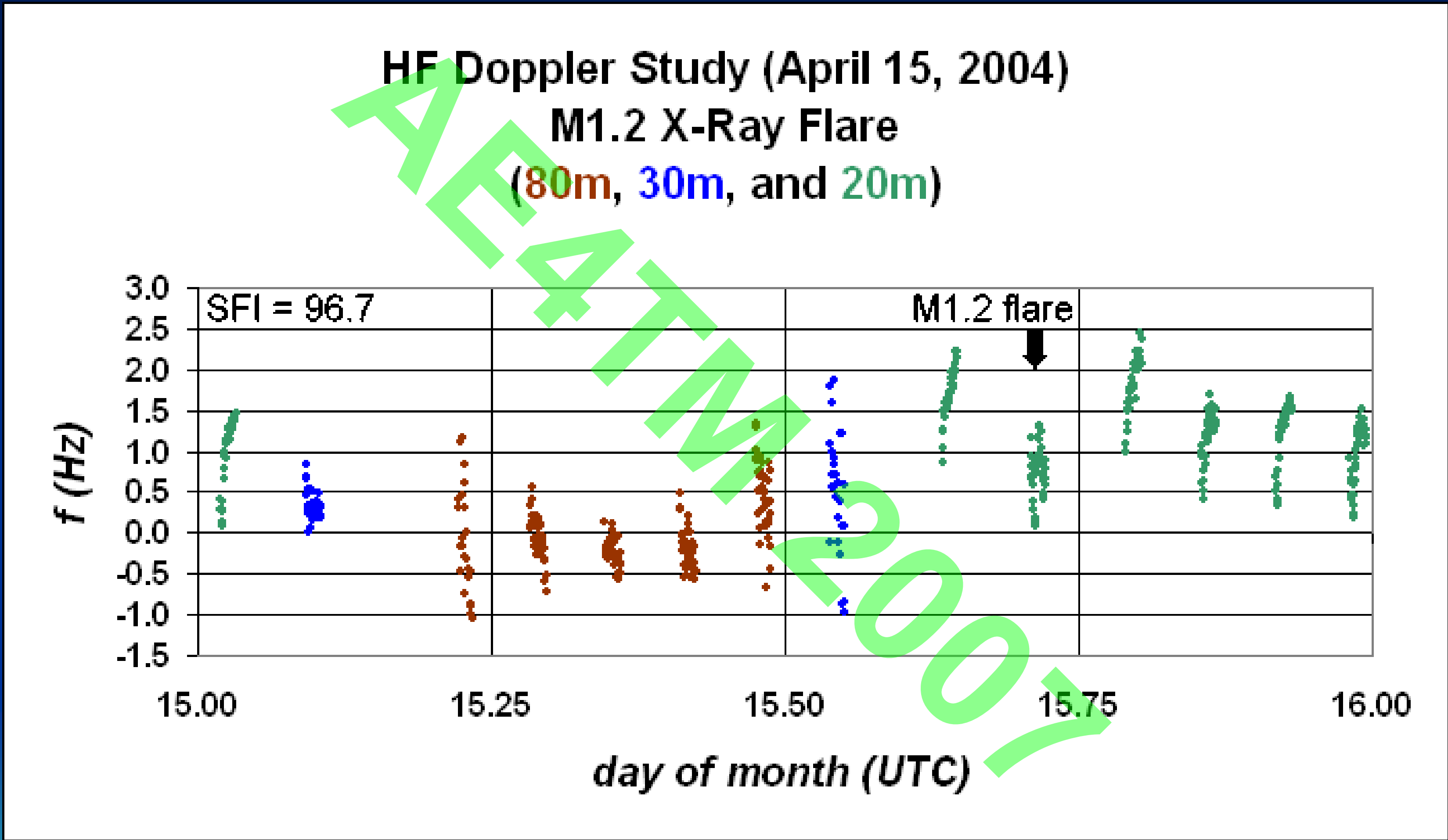
Source & Animation:

http://www.heliotown.com/Radio_Sun_Introduction.html

Long Duration C6.6/1F X-Ray Flare



HF Effect from X-Ray Flare



Summary

- First joint study between amateur radio and SuperDARN OTHR program.
- Doppler fluctuations reveal movements of TID's as well as the rise/collapse of the ionosphere during the day.
- Background radiation measurements suggest that the solar wind is impacting the atmosphere ~50km (~30mi) after initially impacting the F-layer.