

# **Measurement of Traveling Ionospheric Disturbances by Radio Methods Using Transmitters of Opportunity**

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With help from:

Michael Chilcote, Eldred Lee, Eric Tao, Rongfei Lu,  
and David McGaw at Dartmouth

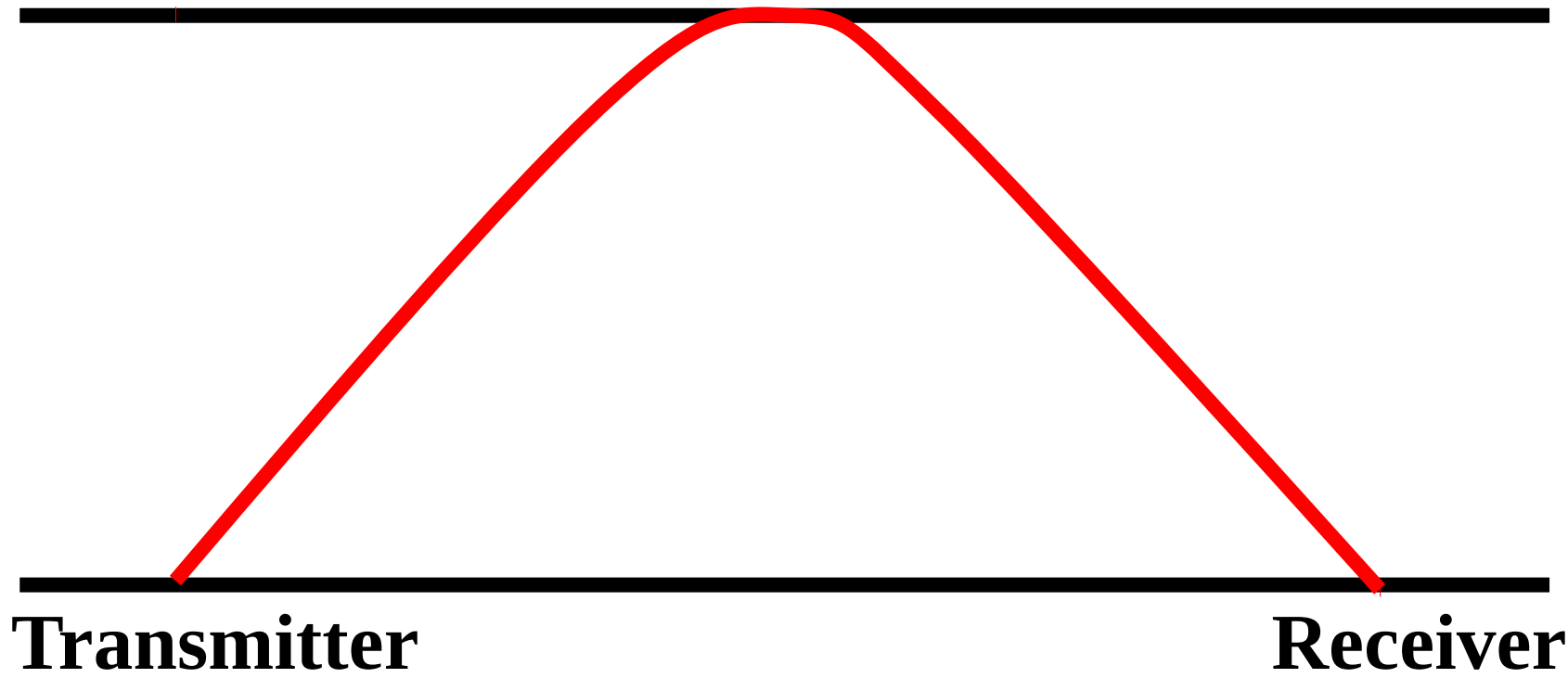
Juha Vierinen and Anthea Coster at MIT/Haystack Observatory

Ivan Galkin at University of Massachusetts Lowell

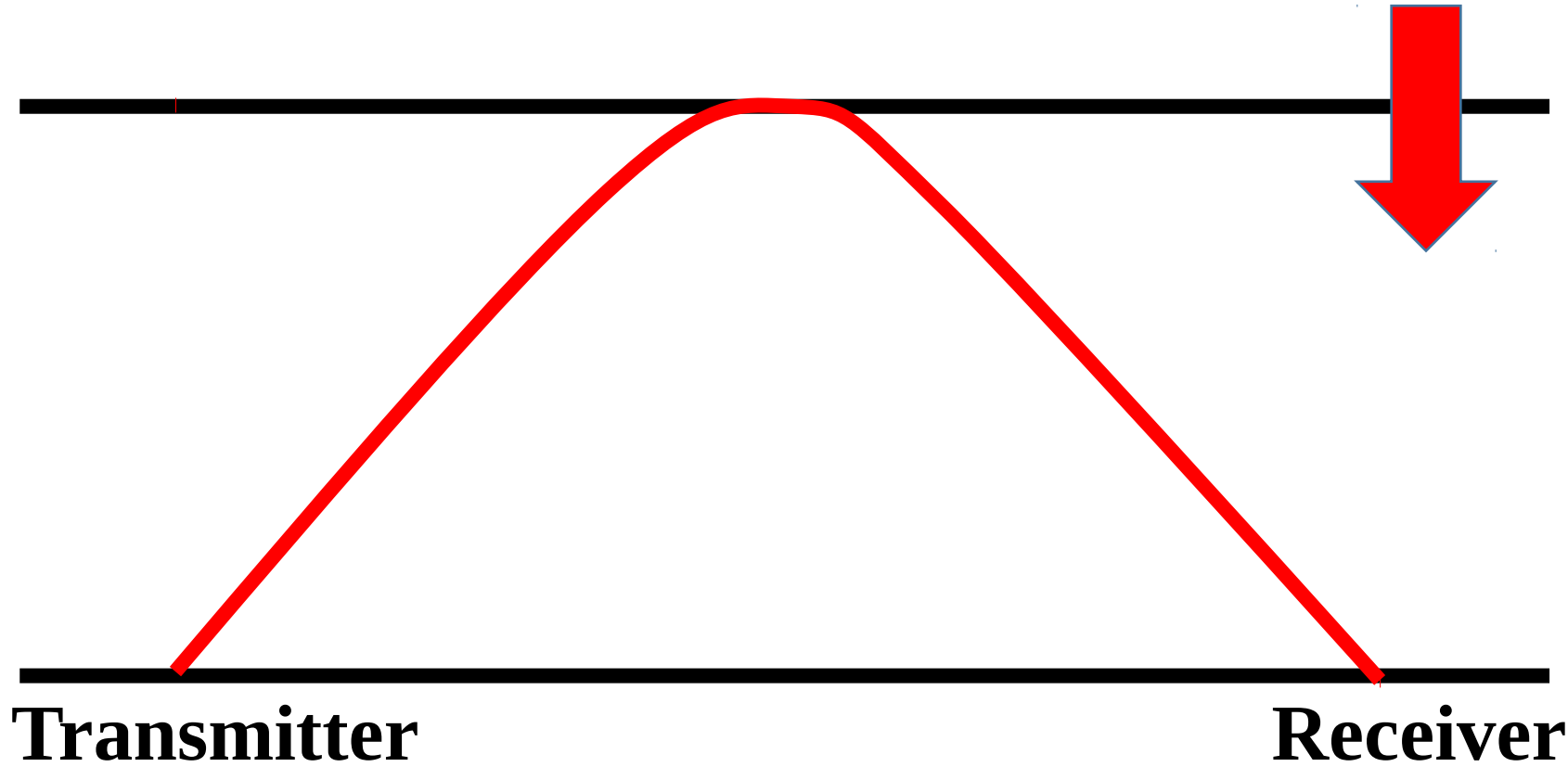
Ethan Miller at JHU/APL

Alan Weatherwax at Siena College/Merrimack College

# Doppler Sounding Principle:

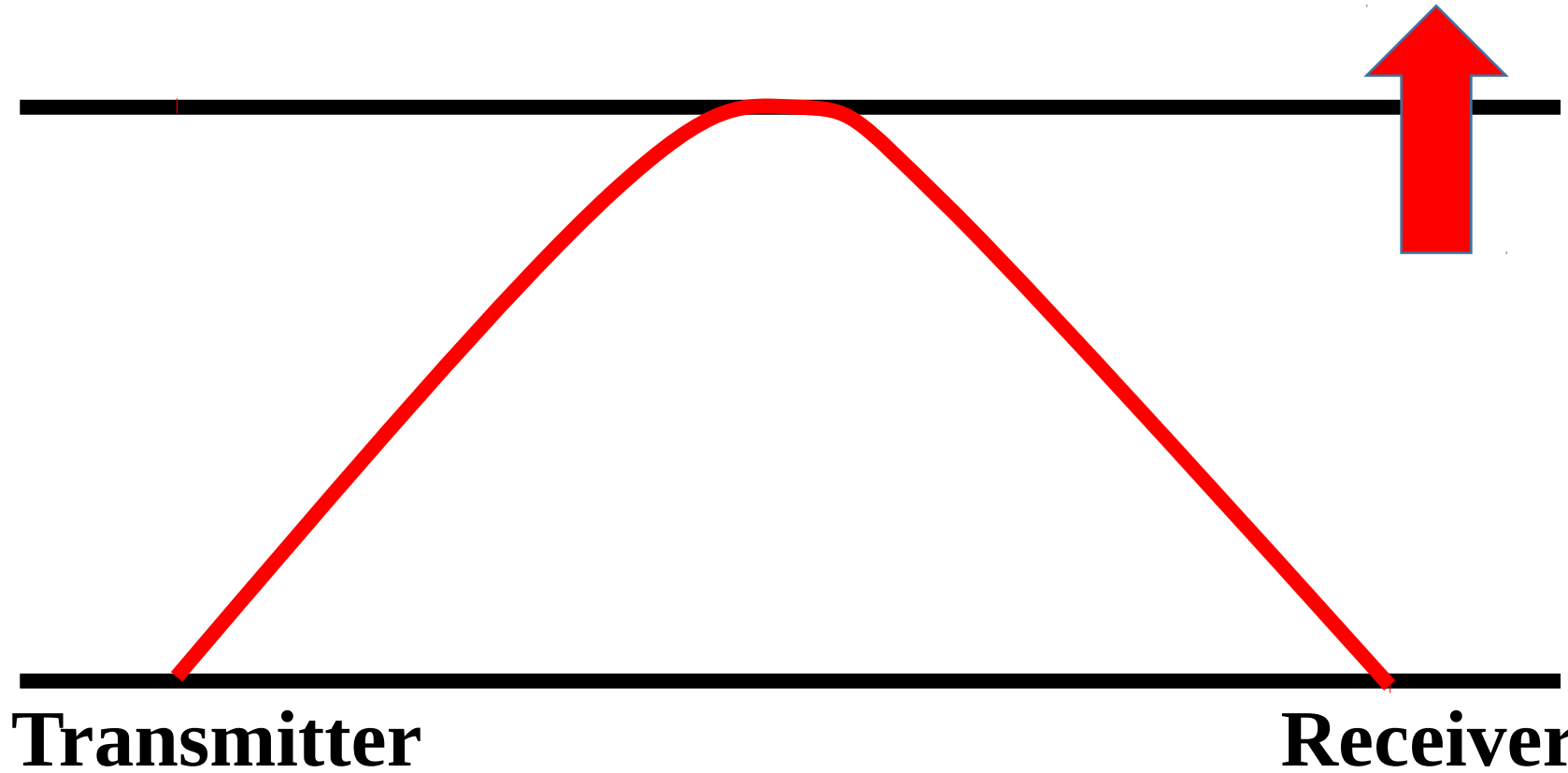


# Doppler Sounding Principle:



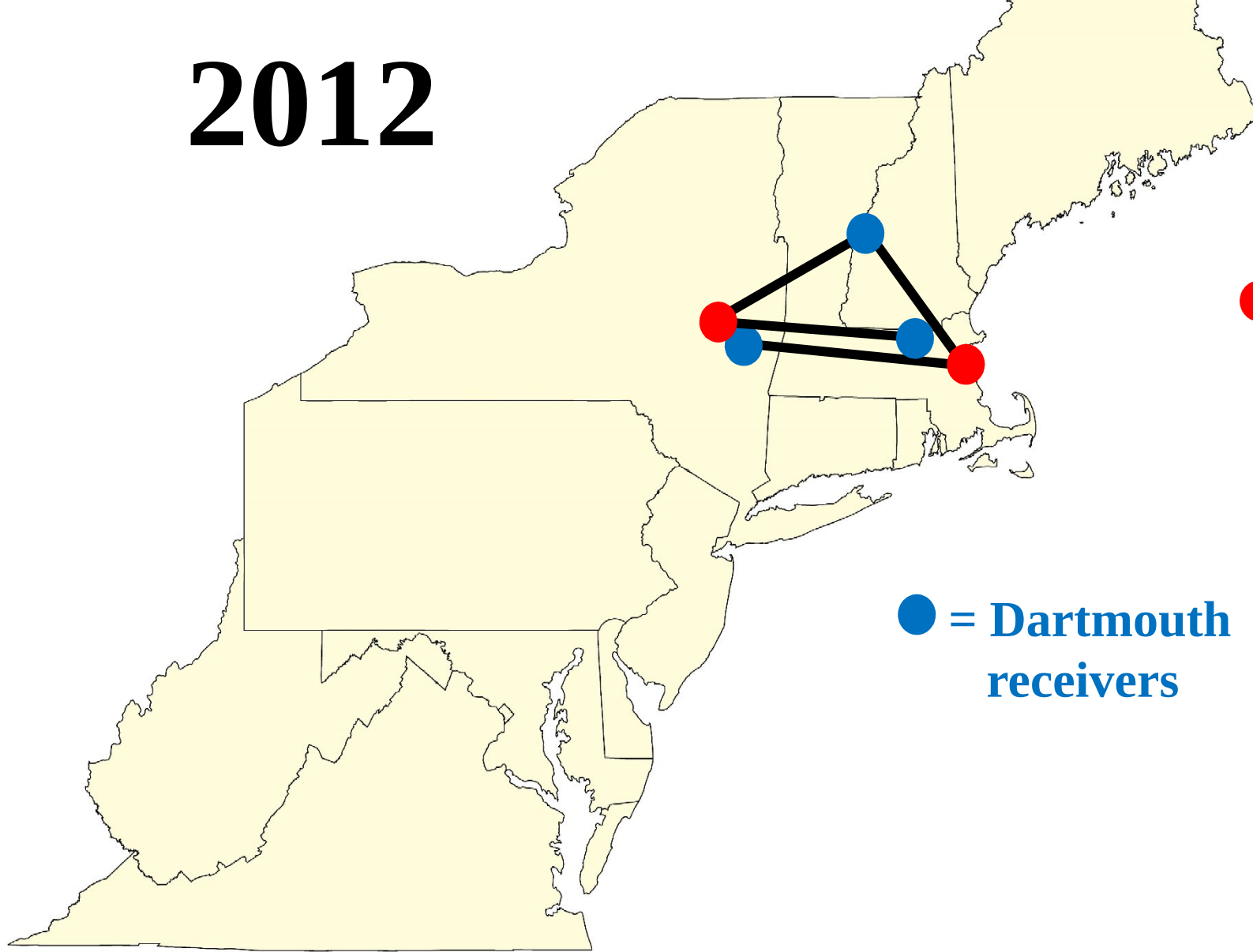
**Descending  
reflecting  
layer □  
Frequency  
Upshifted**

# Doppler Sounding Principle:



**Ascending  
reflecting  
layer** □  
**Frequency  
Downshifted**

# 2012

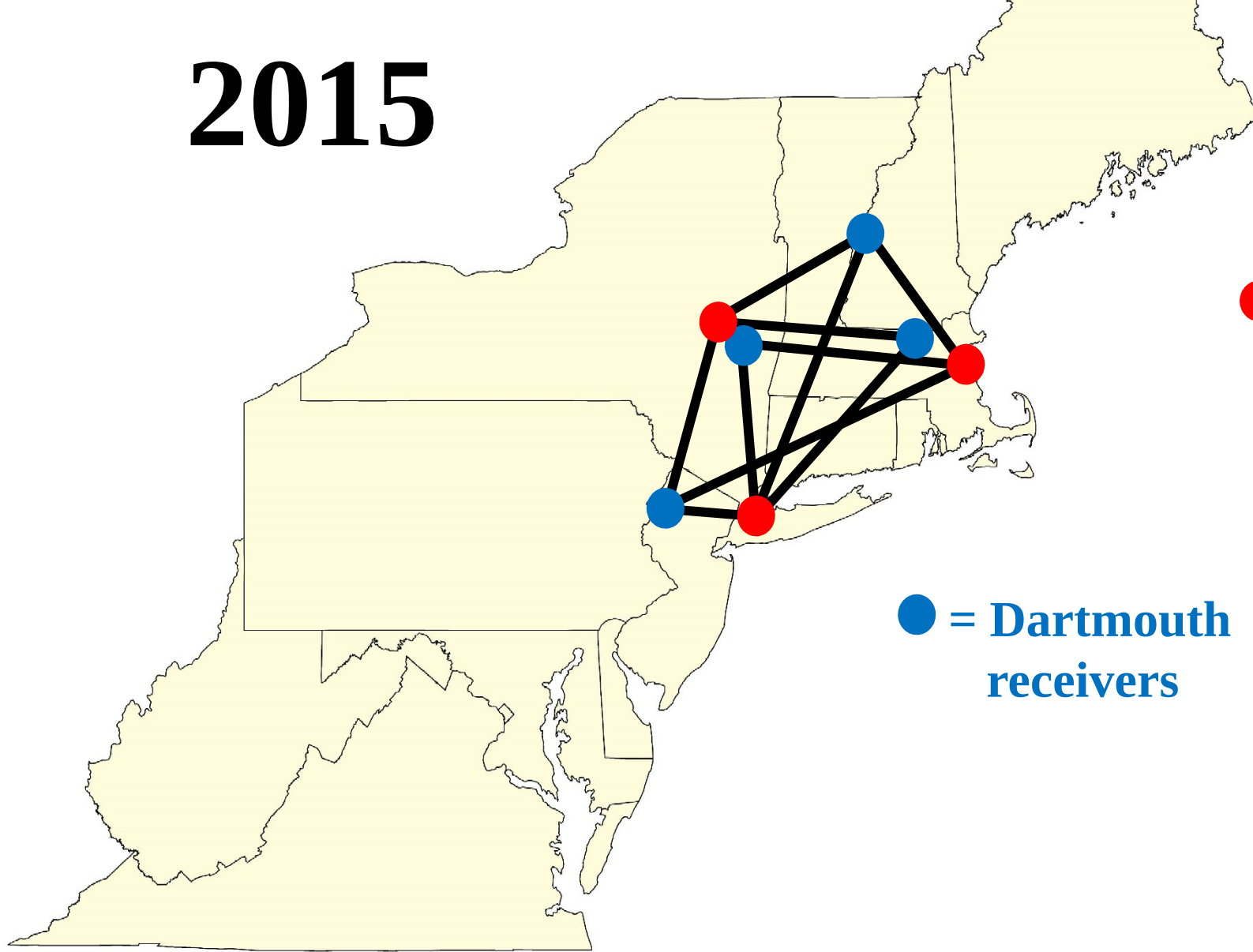


● = Clear-channel

AM radio  
transmitters  
at Boston,  
Schenectady

● = Dartmouth  
receivers

# 2015

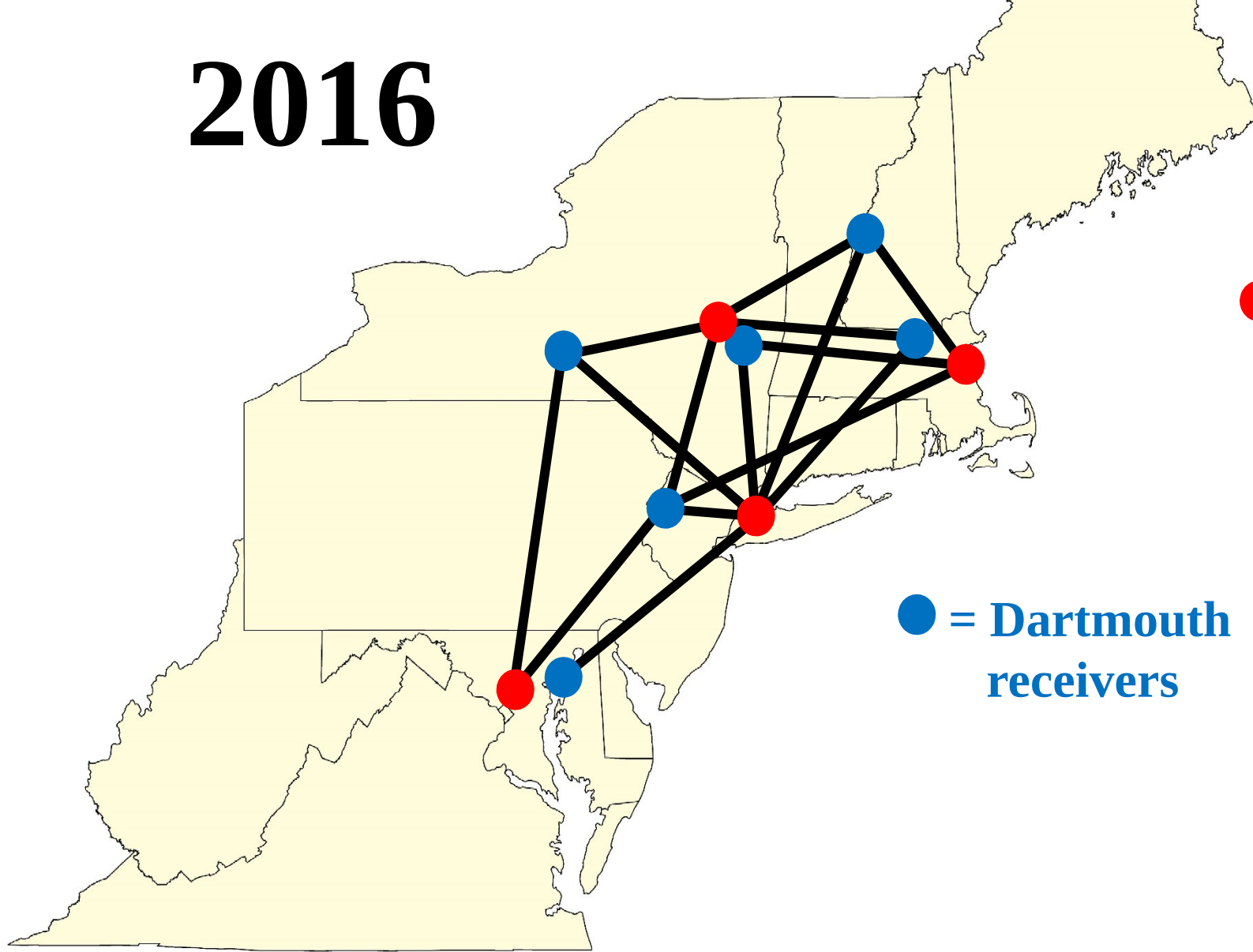


● = Clear-channel

AM radio  
transmitters  
at Boston,  
Schenectady,  
NYC

● = Dartmouth  
receivers

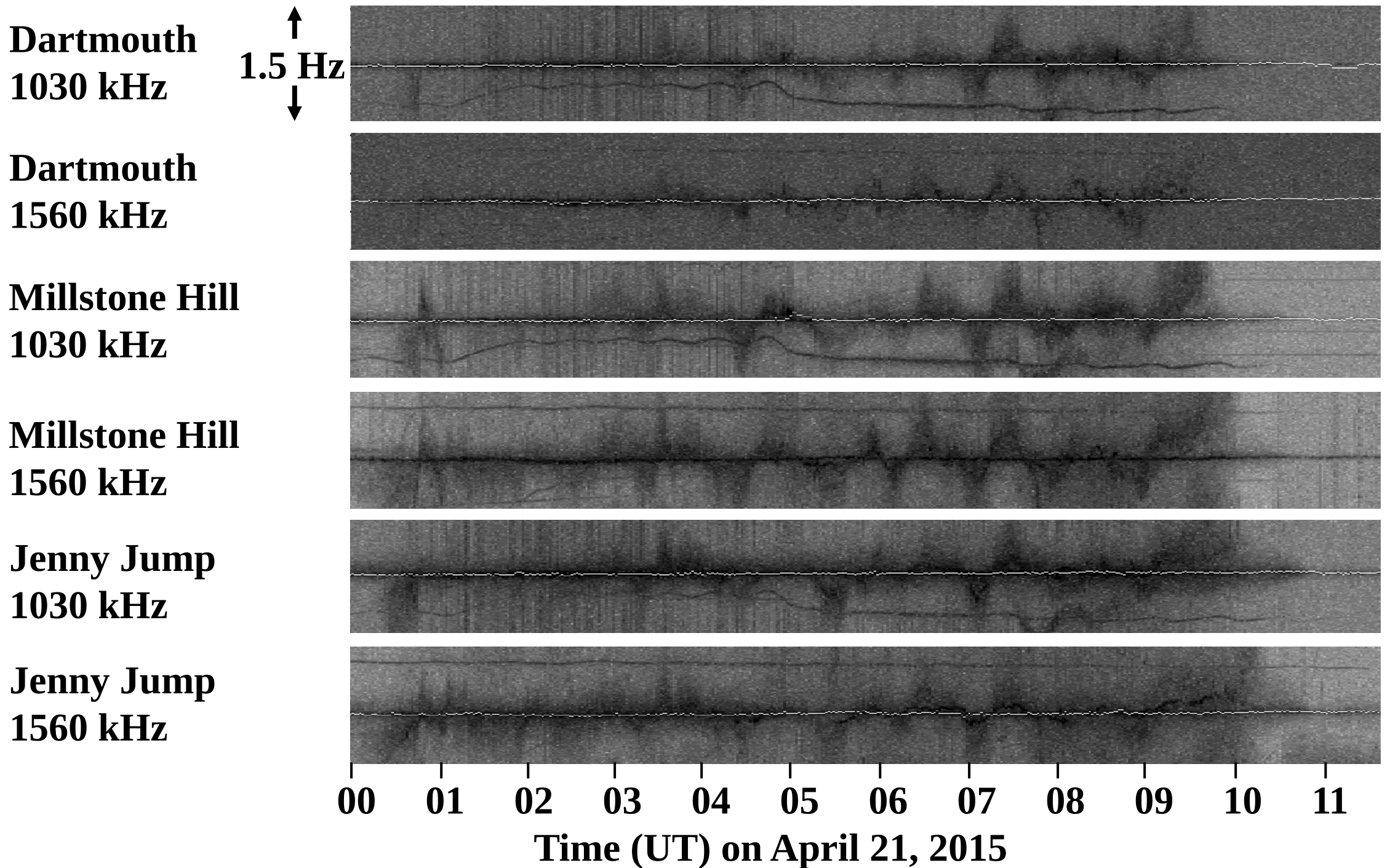
# 2016



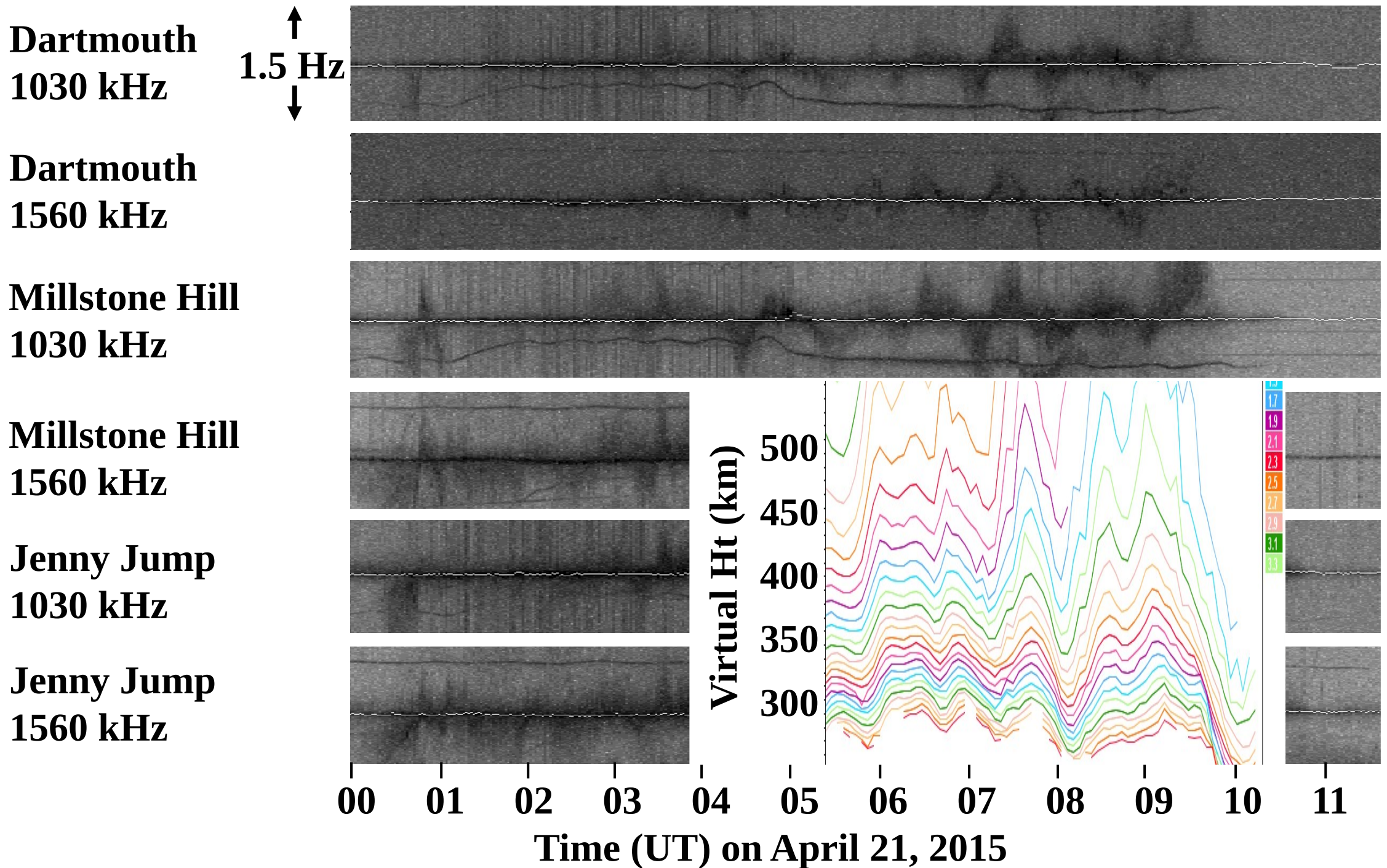
● = Clear-channel

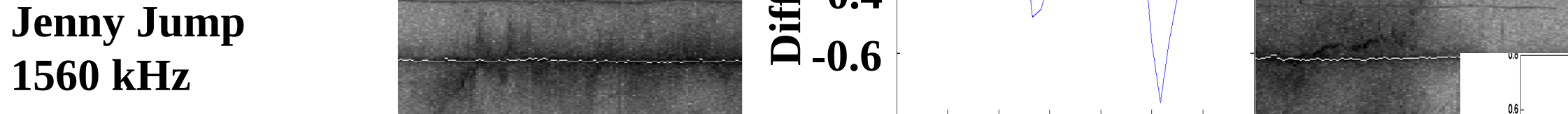
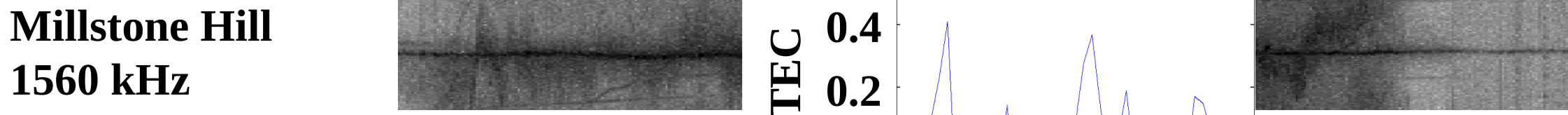
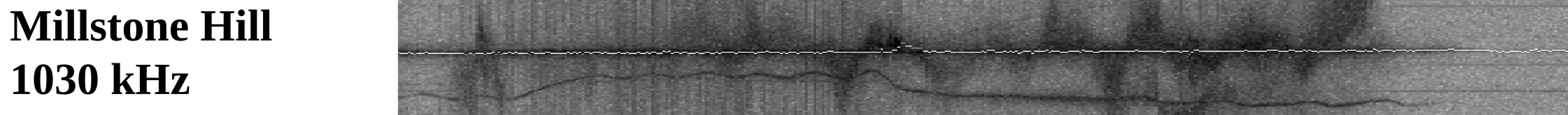
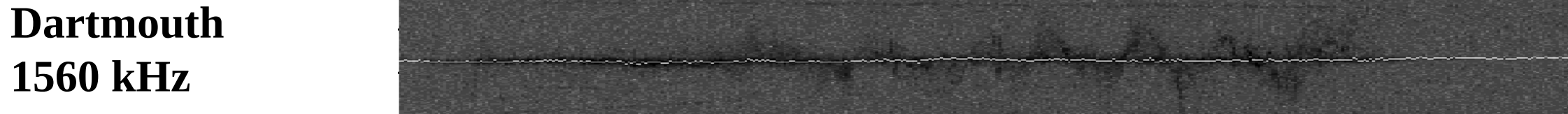
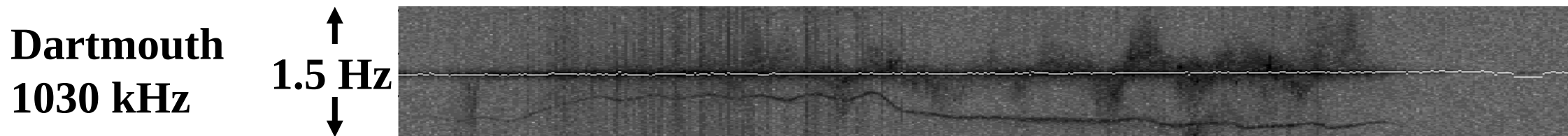
AM radio transmitters at Boston, Schenectady, NYC, Washington

● = Dartmouth receivers



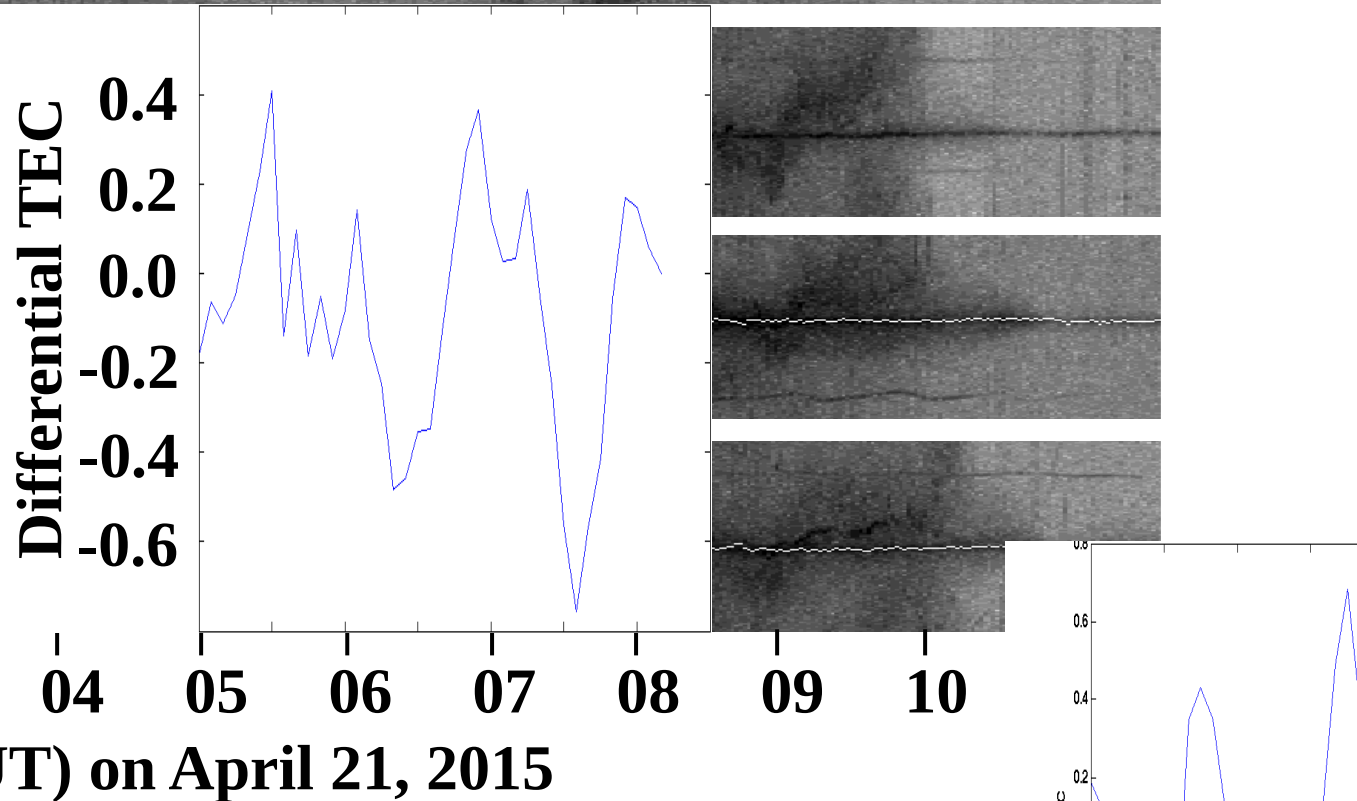




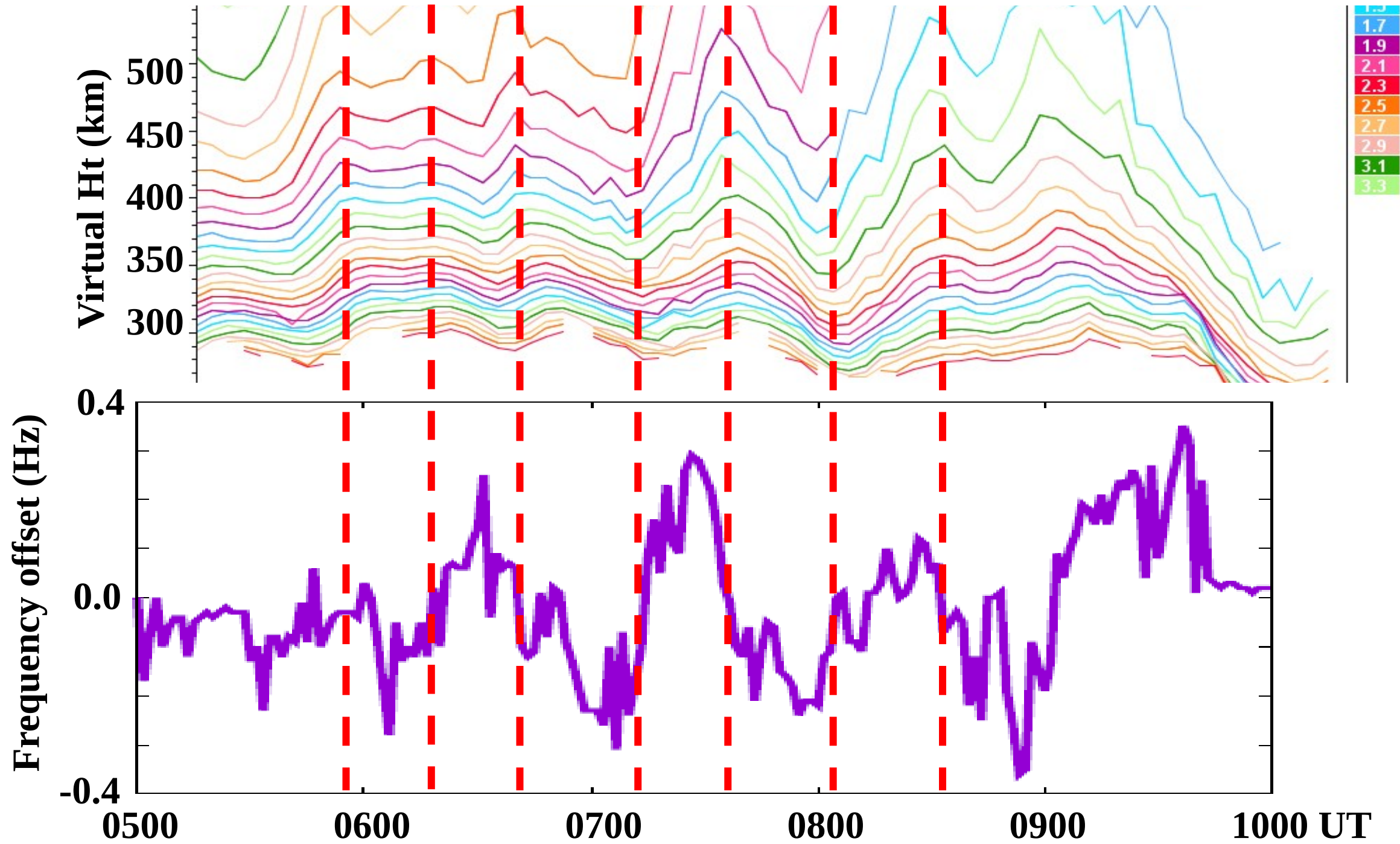


00 01 02 03 04 05 06 07 08 09 10

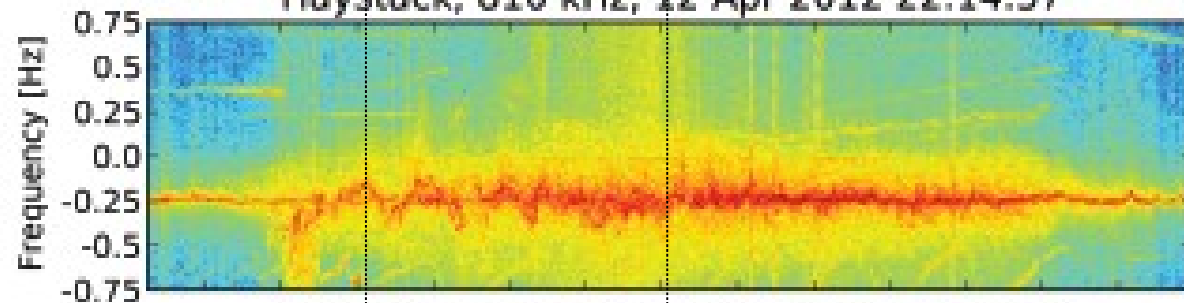
Time (UT) on April 21, 2015



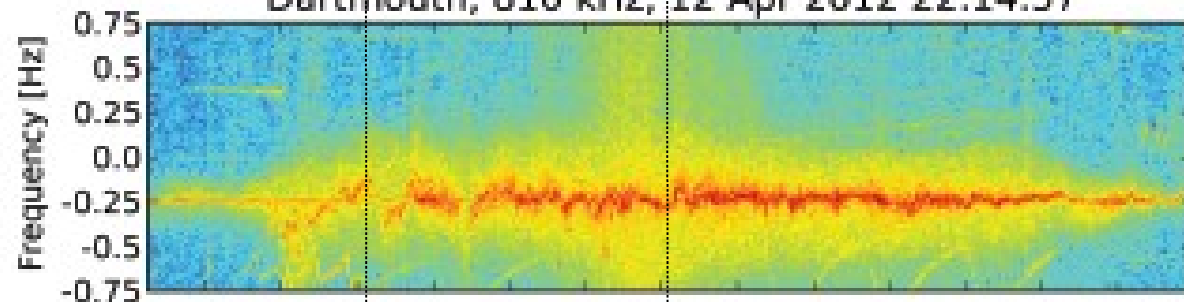




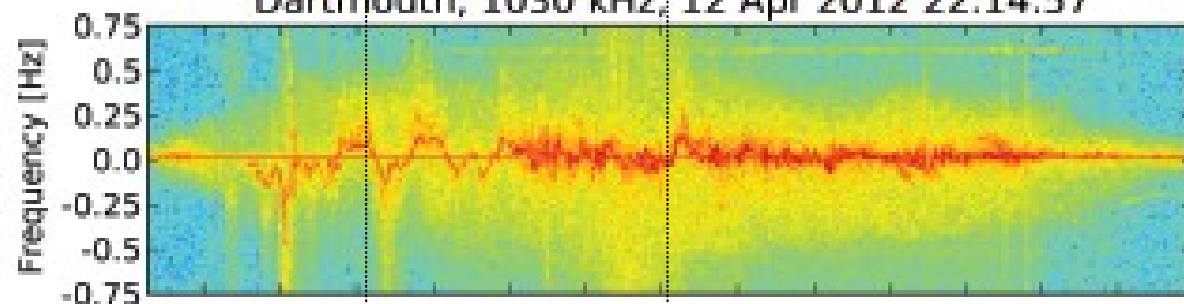
Haystack, 810 kHz, 12 Apr 2012 22:14:57



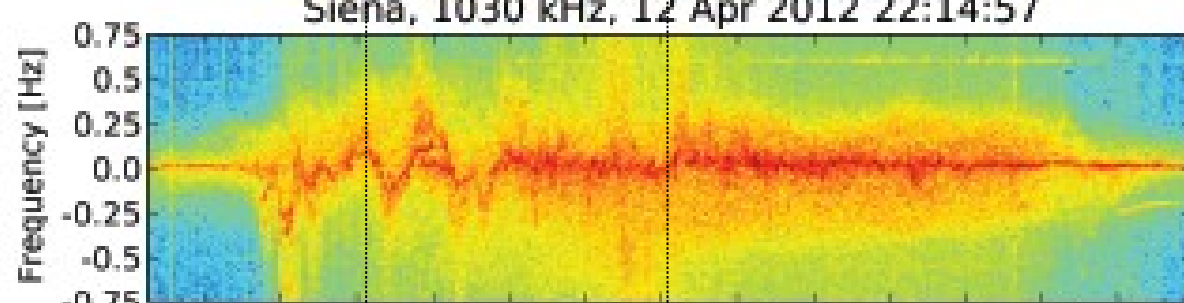
Dartmouth, 810 kHz, 12 Apr 2012 22:14:57



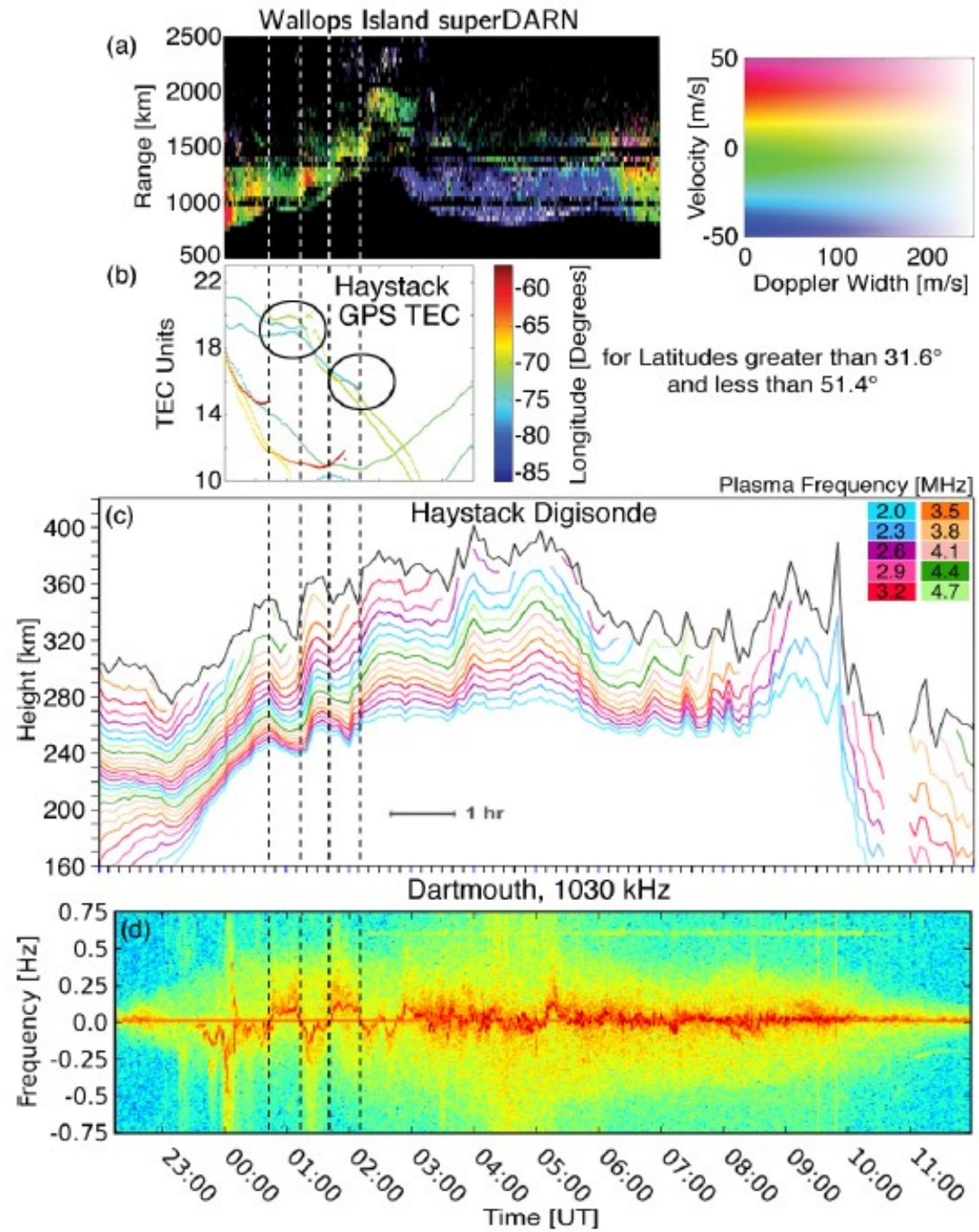
Dartmouth, 1030 kHz, 12 Apr 2012 22:14:57



Siena, 1030 kHz, 12 Apr 2012 22:14:57

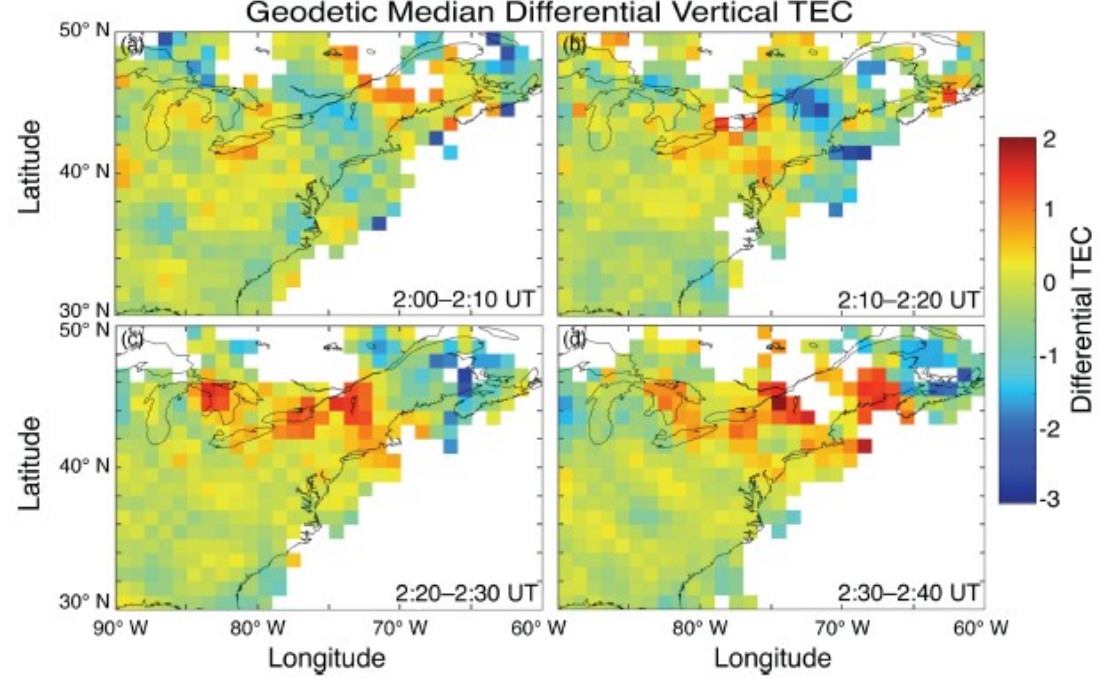


Time [UT]  
23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00

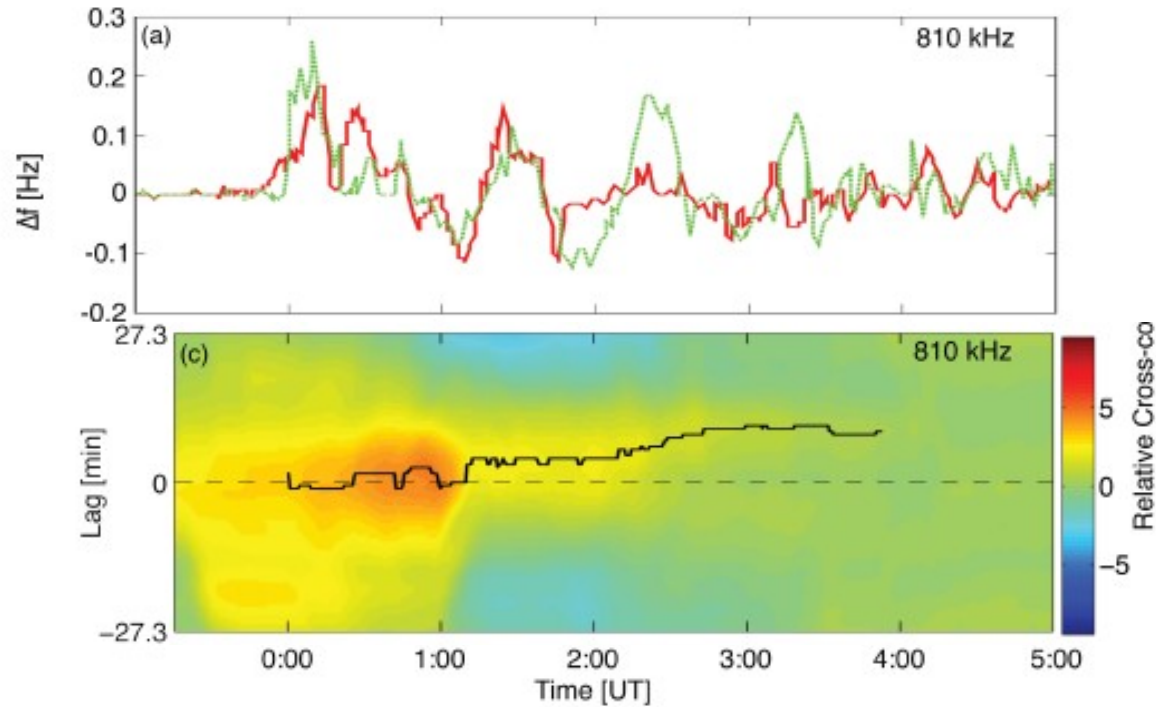




**GPS:**



**AM  
Doppler:**





## Antenna/Pre-amp/interface box <\$100

Mixer/filter \$50

Mini-computer \$35



Dongle  
Software  
Defined  
Radio \$15

(not shown)  
GPS with  
1 PPS output

## Summary

**Doppler sounding of commercial AM radio stations can effectively measure Traveling Ionospheric Disturbances**

**Multiple baselines show promise for determining phase velocities and directions of propagation.**

**Hardware cost for a single station may be under USD300.**

**More about this technique: Detection of traveling ionospheric disturbances by medium-frequency Doppler sounding using AM radio transmissions, by M. Chilcote, J. LaBelle, F. D. Lind, A. J. Coster, E. S. Miller, I. A. Galkin, and A. T. Weatherwax, *Radio Science*, vol. 50, doi:10.1002/2014RS005617, 2015.**







