The Silent Sounds of Tornadoes and Their Potential Fluid Mechanism

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Abstract

Sound at frequencies below the nominal bound of human hearing (˜20 Hz) is called "infrasound." Infrasound at frequencies between 0.5 and 10 Hz has been observed to be emitted by tornado-producing storms throughout the life of the tornado, including tornadogenesis. Due in part to the low atmospheric attenuation at these low frequencies, infrasound monitoring is a good candidate for long-range passive tornado monitoring, especially in hilly terrain where line-of-sight limits radar (e.g. Southeast United States). However, the fluid mechanism(s) responsible for the infrasound must be identified to enable researchers to interpret these currently unused signals. This is the objective of the current research, which has used multiple infrasound measurement modalities to identify correlations between received infrasound signals and storm processes. This includes a fixed infrasound array, a mobile infrasound array, and a single infrasound microphone carried by a storm chaser. An overview of select events will be presented, including measurements from an EFU tornado on 11 May 2017 that was within 20 km of the fixed array. These tornadic and non-tornadic observations will then be used to identify potential physical mechanisms.

The Silent Sounds of Tornadoes and Their Potential Fluid Mechanism

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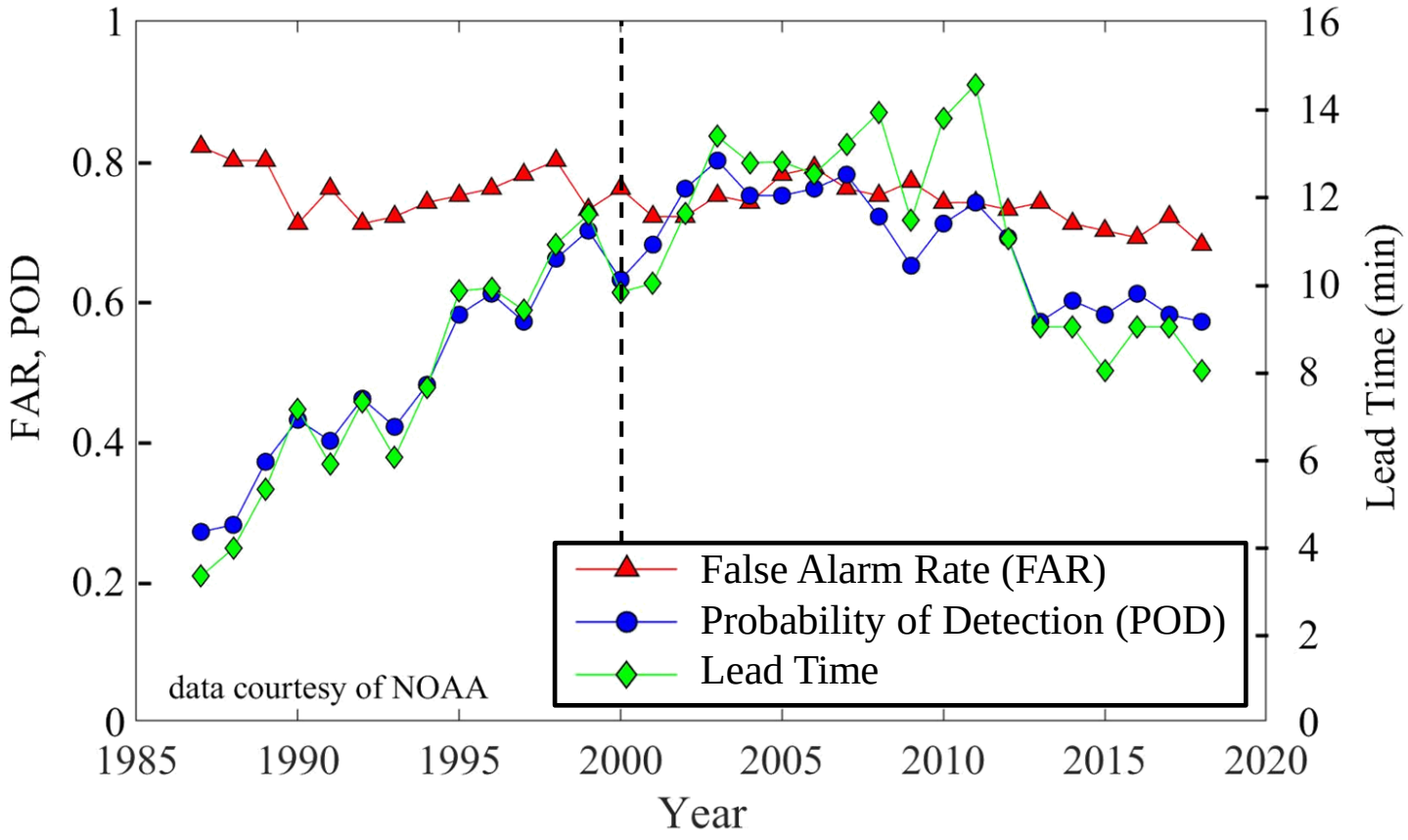
Tornadoes are “small” coherent structures that rarely occur.

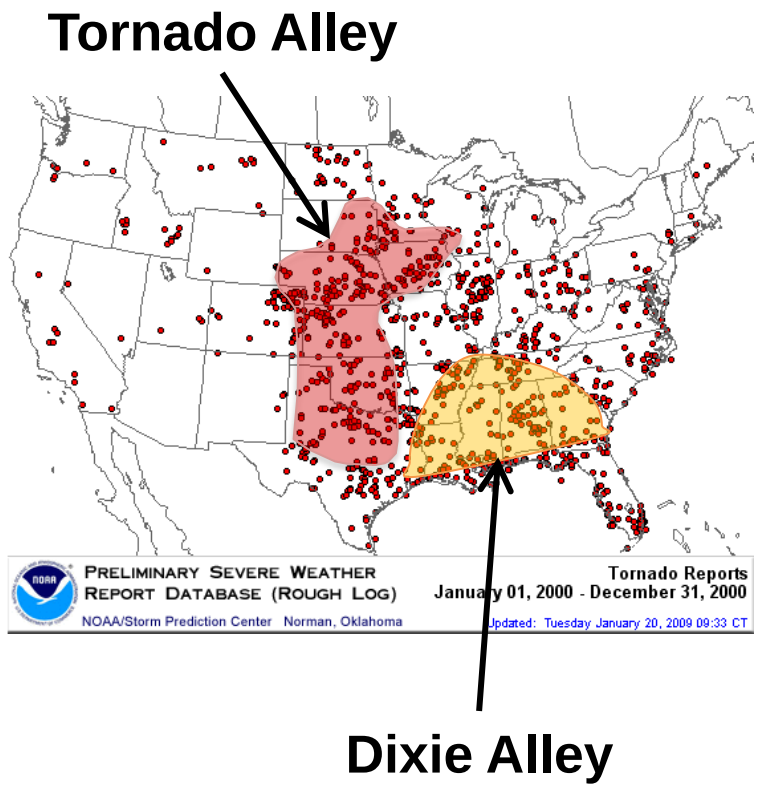
However, tornadoes are also catastrophic.

Vilonia, Arkansas
April 27, 2014 (16 killed)

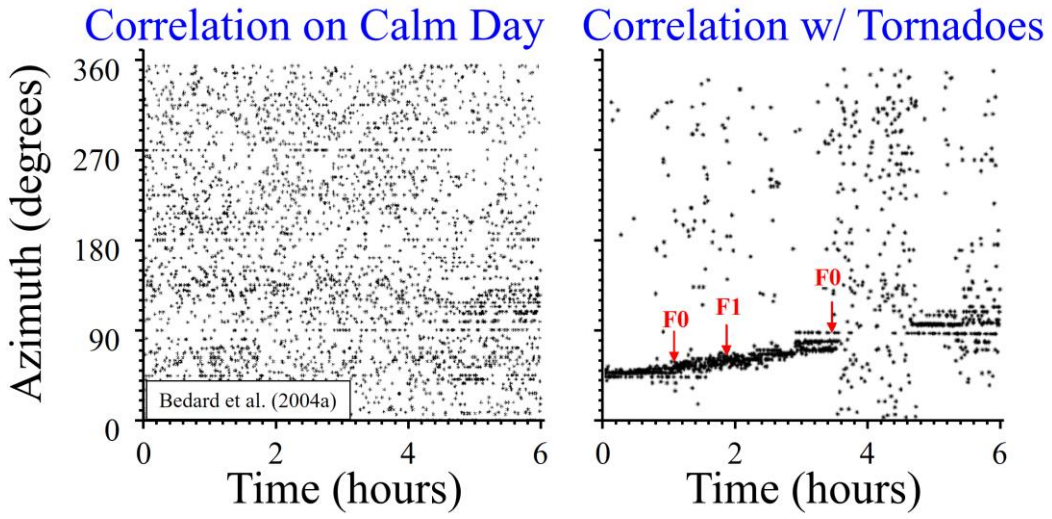
Joplin, Missouri
May 22, 2011 (158 killed)

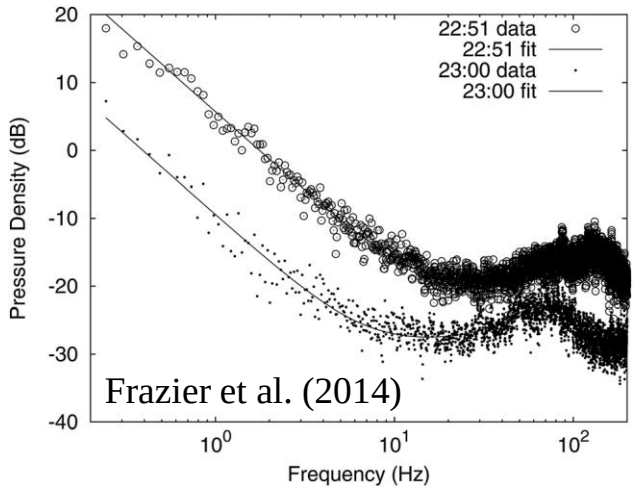
Improvements in tornado warnings is needed, especially for Dixie Alley.

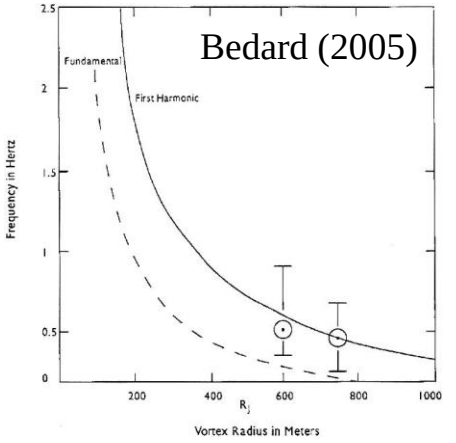


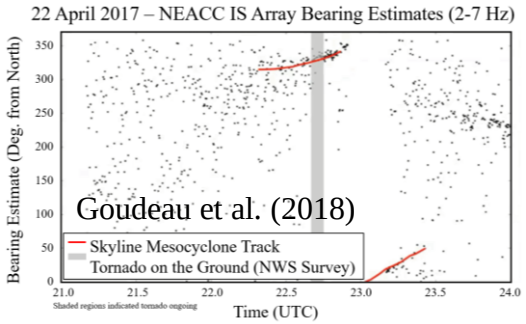


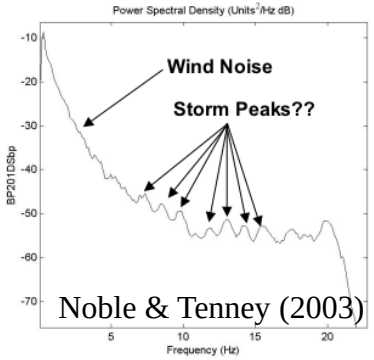
Low frequency sound from tornadoes has potential to provide a new data source.

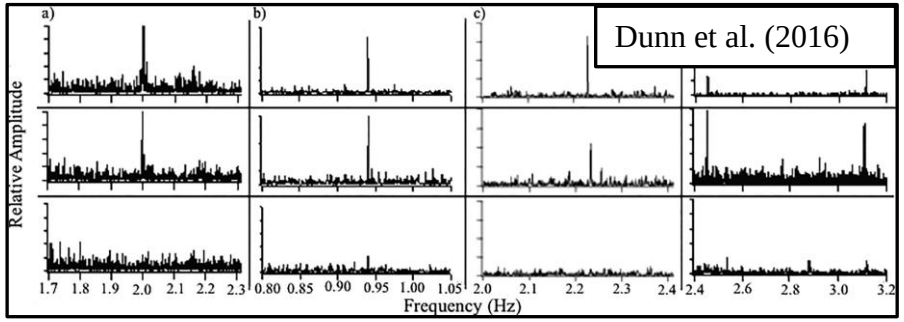


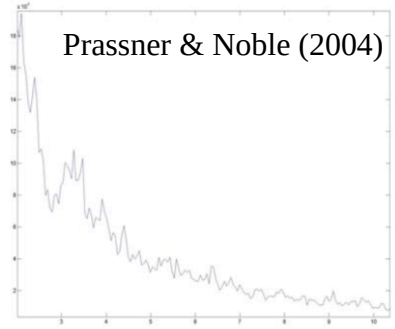






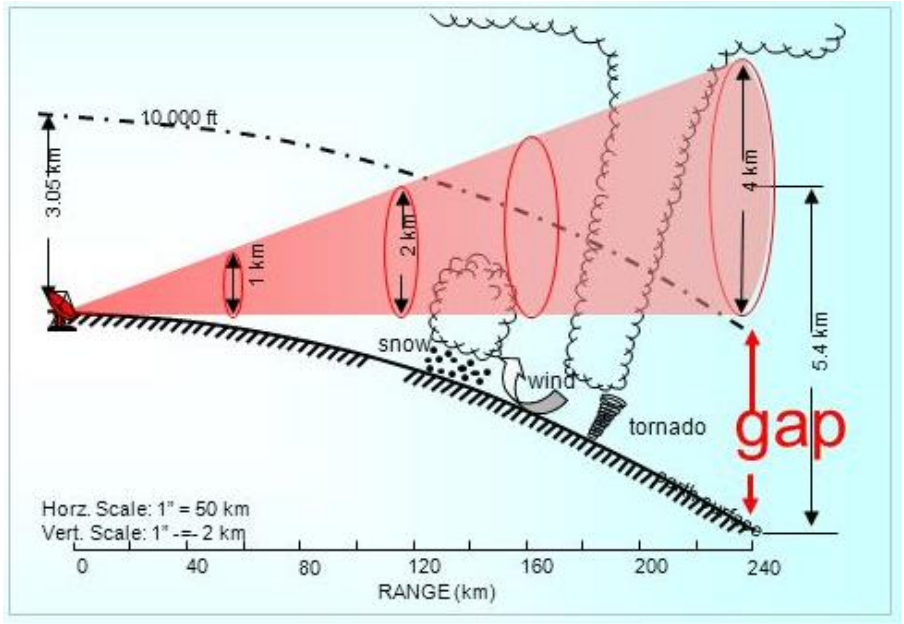




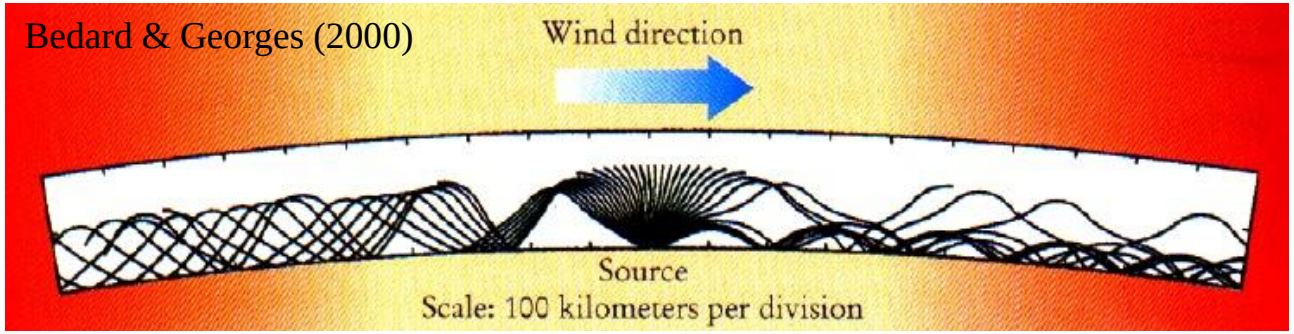


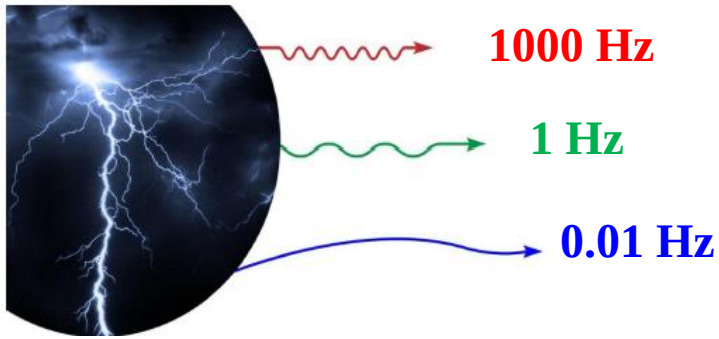
Infrasound is sound at frequencies below human hearing that has unique properties.

Radar is a Line-of-Sight Measurement



Infrasound can go beyond line-of-sight





1000 Hz

1 Hz

0.01 Hz

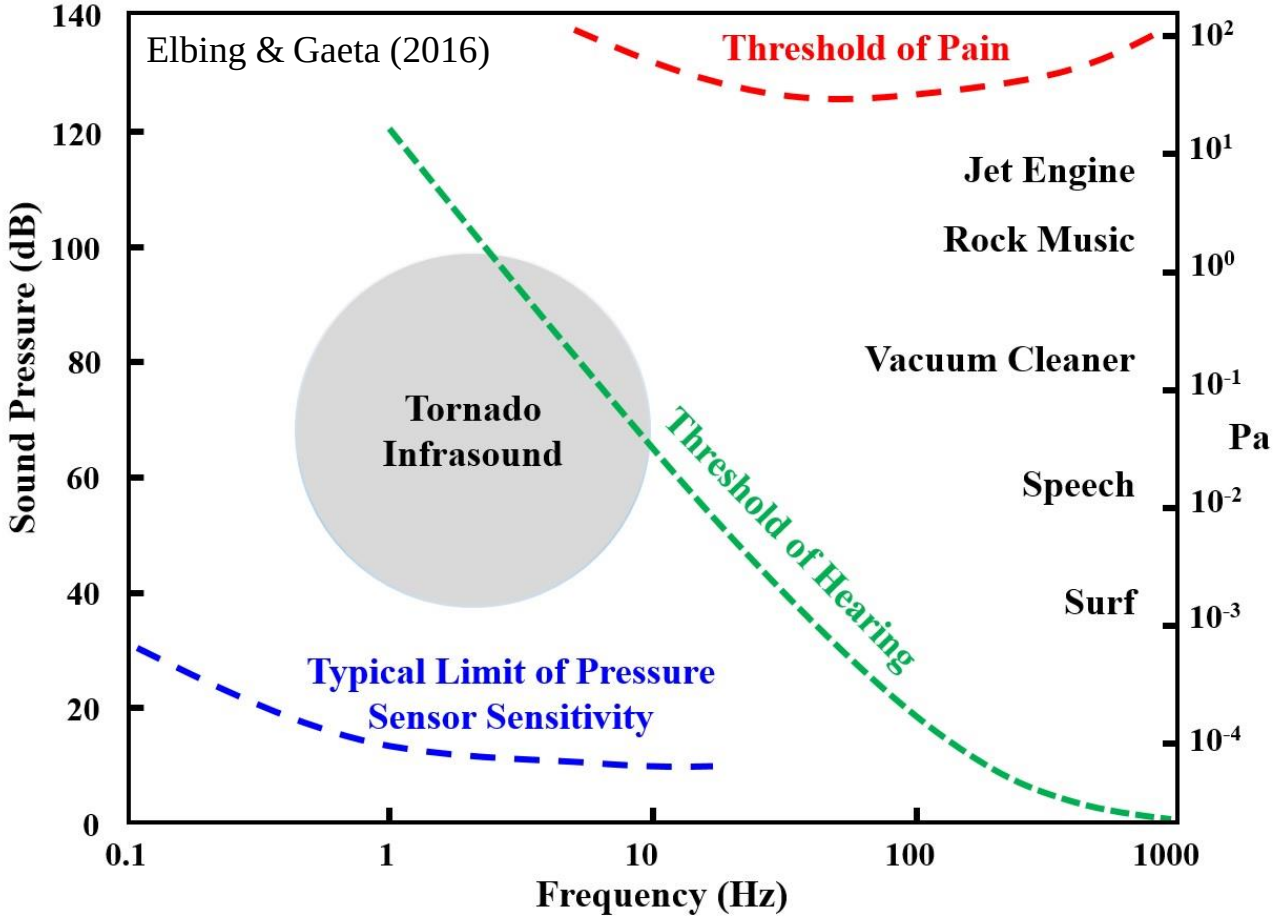
90% of energy absorbed

~7 km (4.3 miles)

3000 km (1,800 miles)

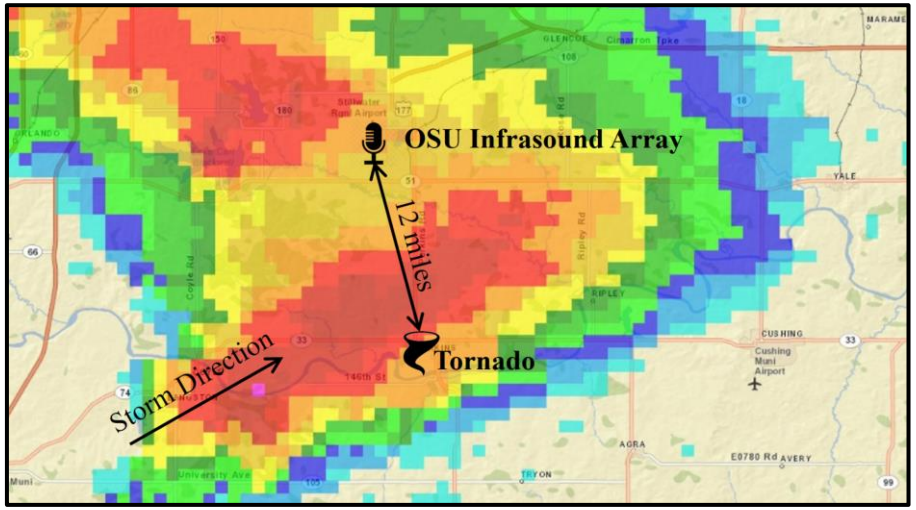
Earth's circumference

So tornadoes produce this sound…how do we make use of this fact?



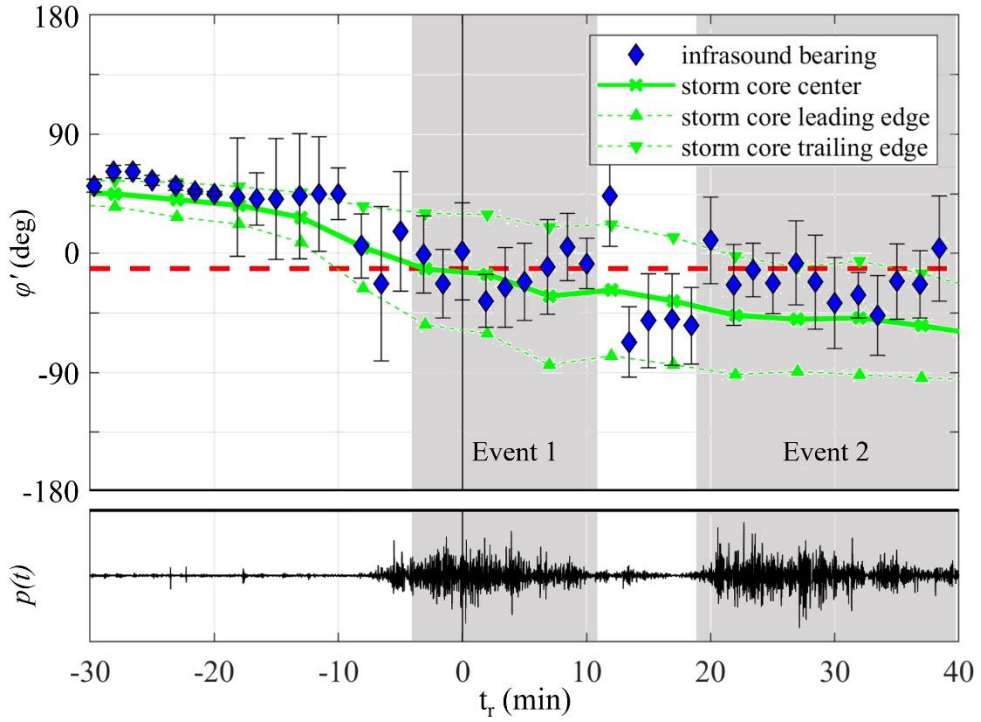
We have been monitoring for tornado infrasound since 2016.

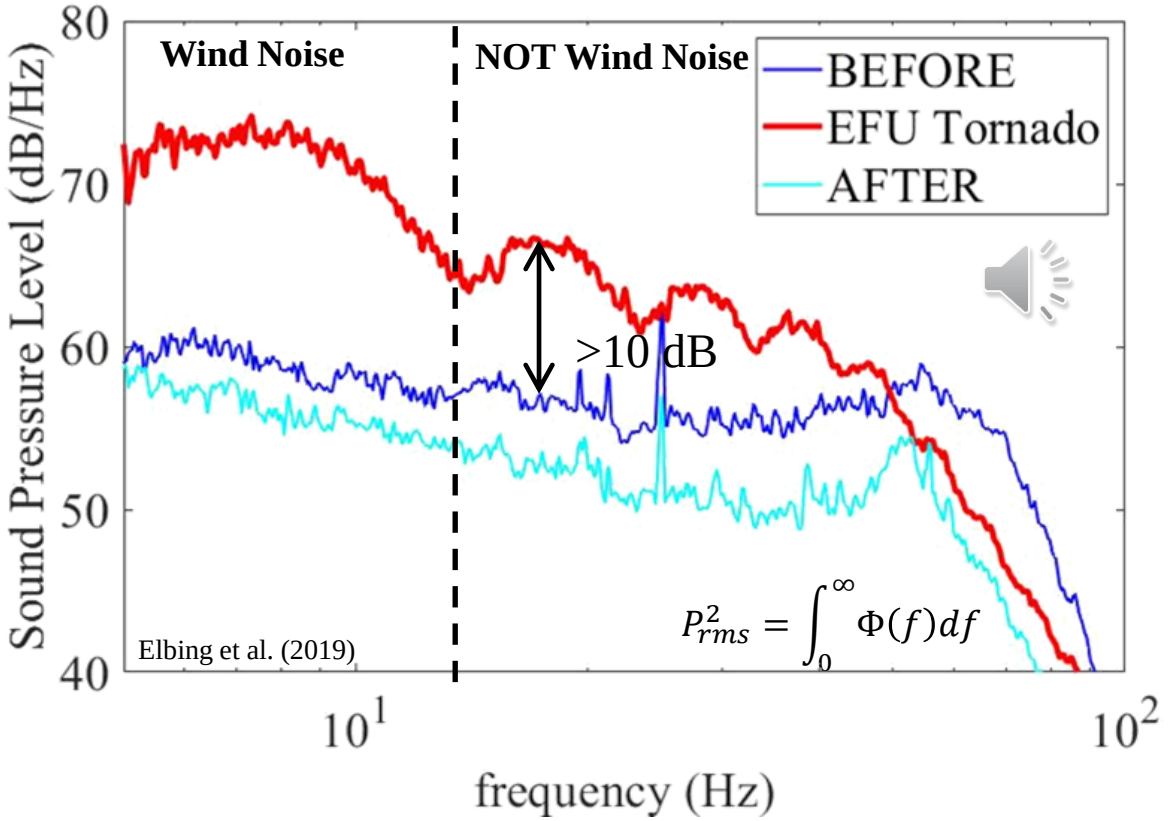
Our first tornado with radar and infrasound observations was in May of 2017.




Meteorologists Juston Drake and Simon Brewer

This EFU tornado produced a signal with a fundamental frequency of 8.3 Hz.

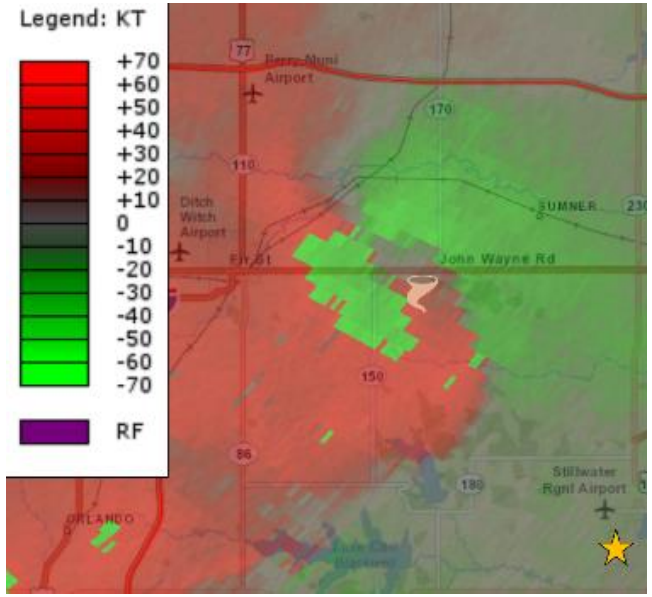




There were a lot of tornadoes in 2019…did not produce many observations.

EF1 Tornado

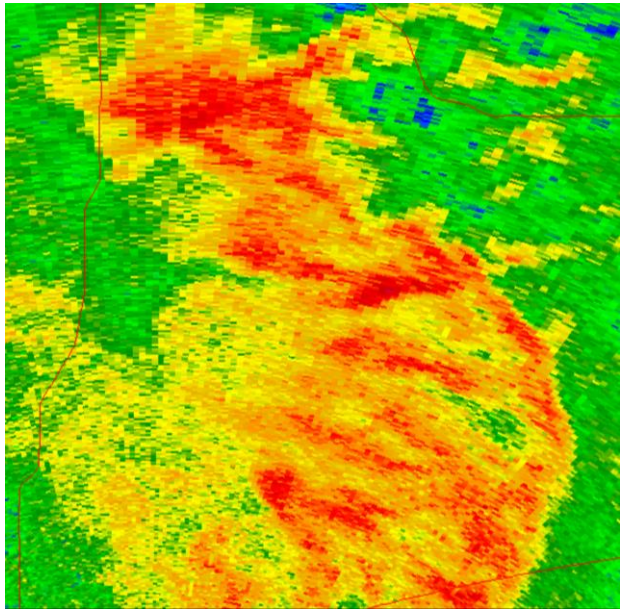
Sumner, OK (6 May 2019)



No radar available

EF0 QLCS Tornado

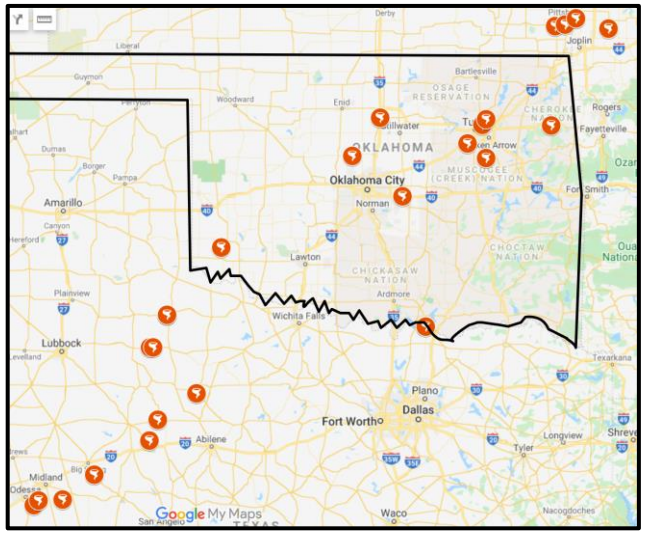
Stillwater, OK (18 May 2019)



No radar available

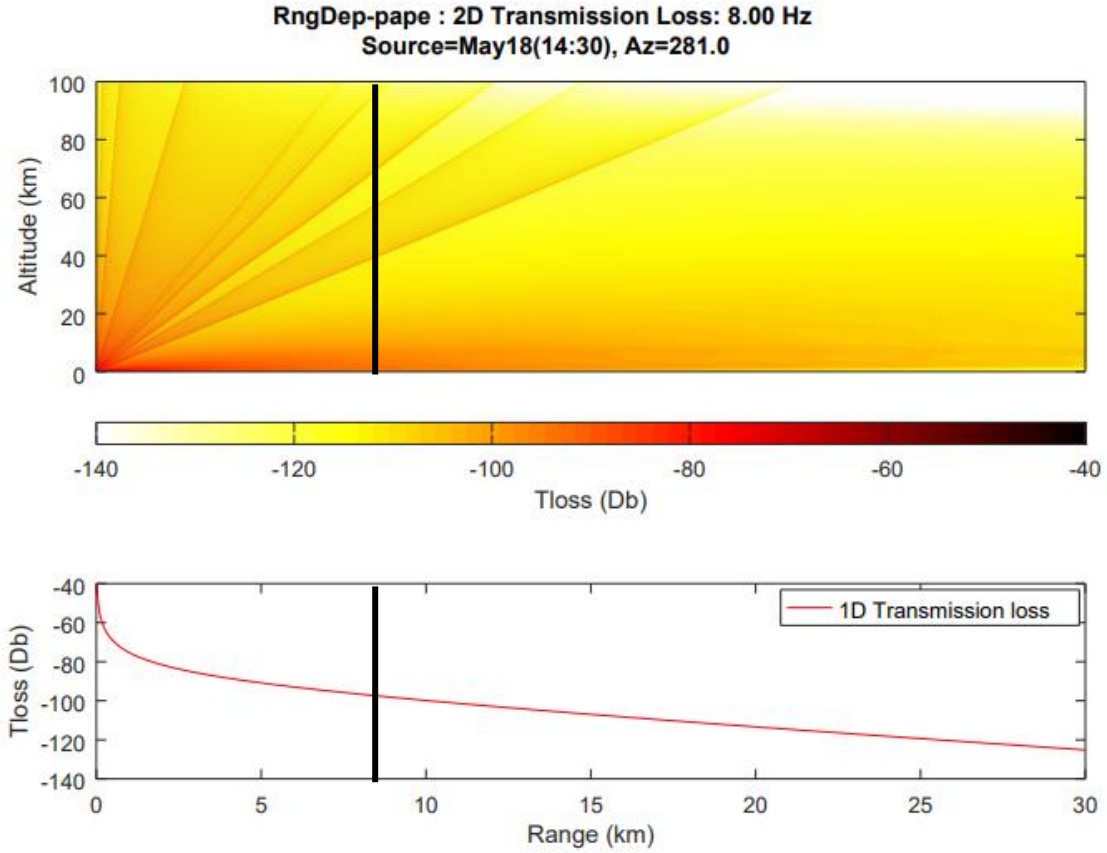
Tornado Outbreak

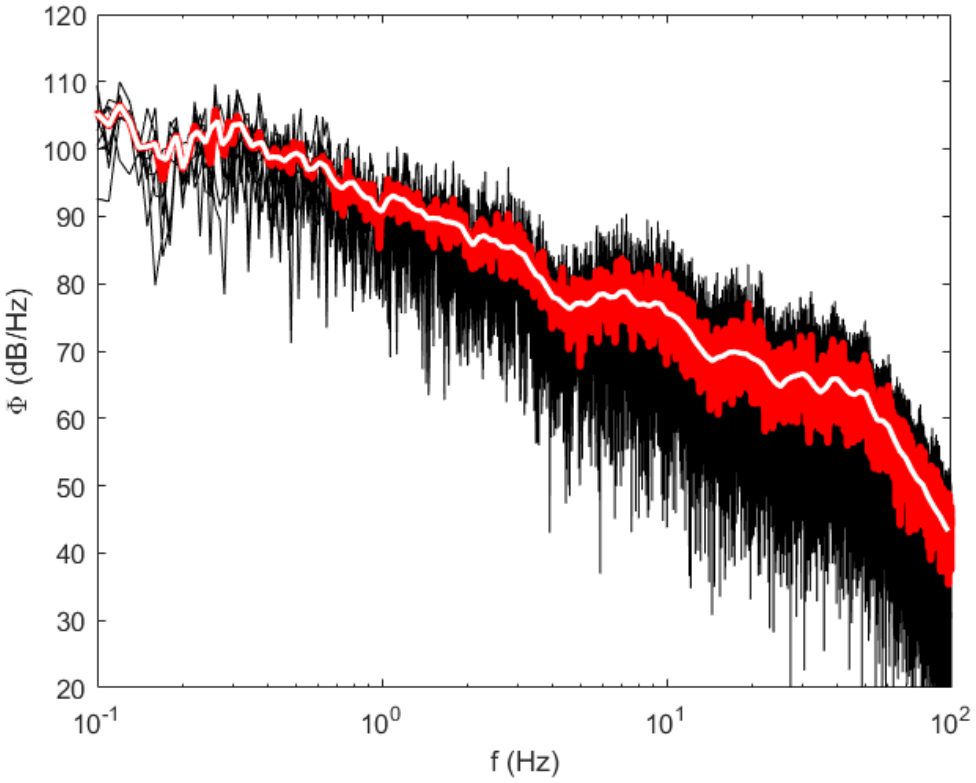
TX-OK-MO (20 May 2019)



No radar with infrasound available

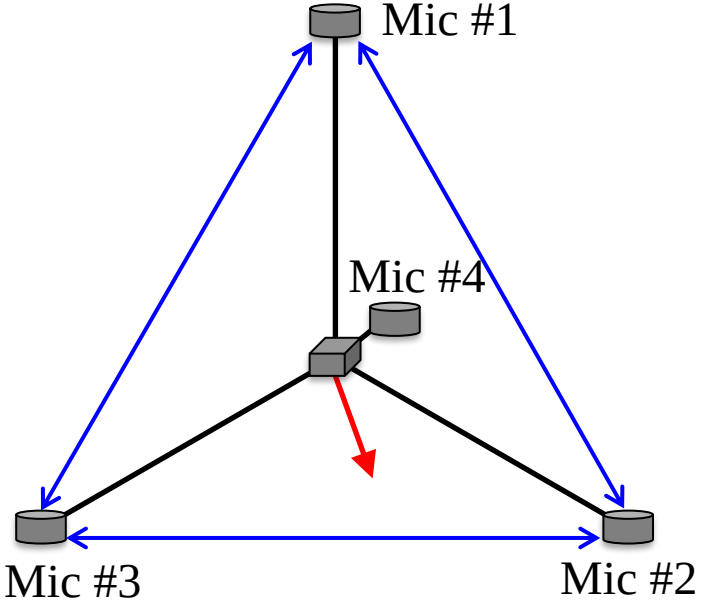
Did capture tornado spectra on 18 May 2019 with similar spectra to first observation.





In 2020 we created mobile infrasound capabilities to increase likelihood of observations.

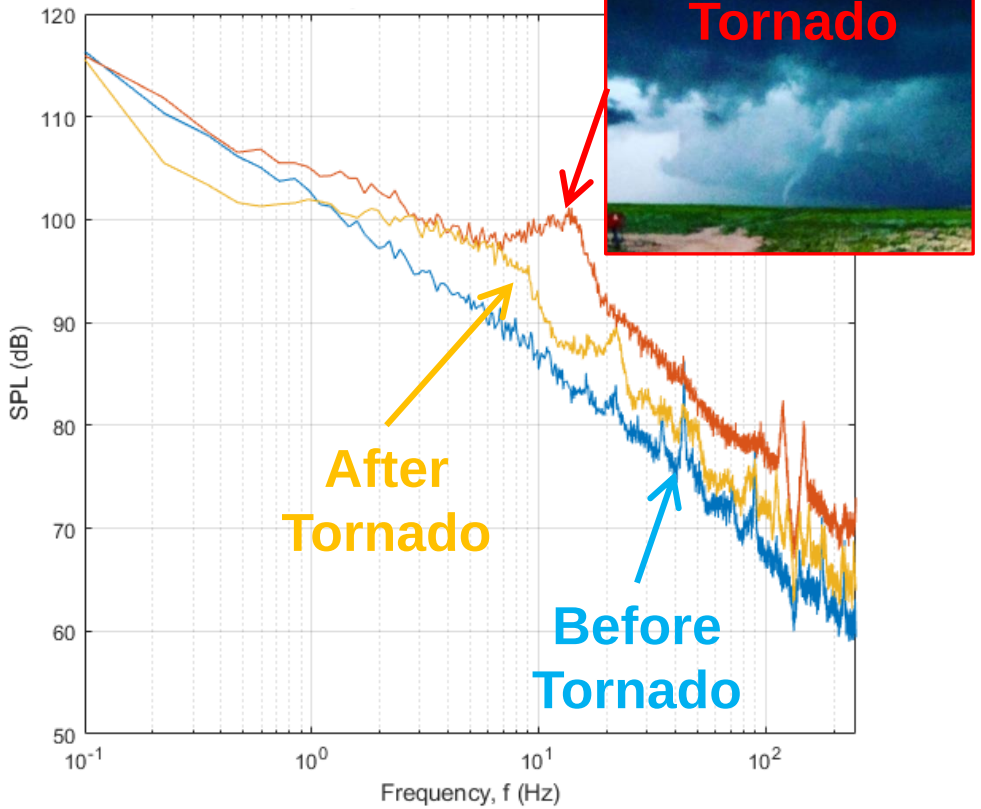
Mobile Infrasound Array



Storm Chaser

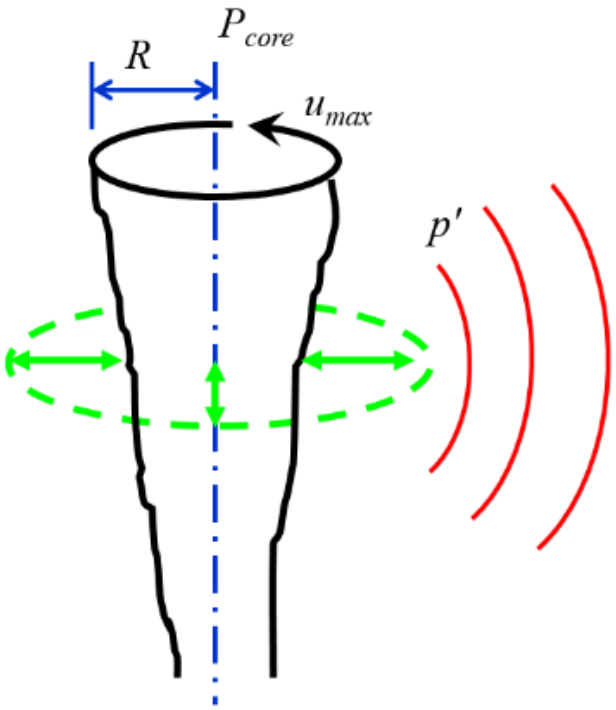
Solar Balloons

The storm chaser captured a small tornado in Lakin, Kansas on 22 May 2020.

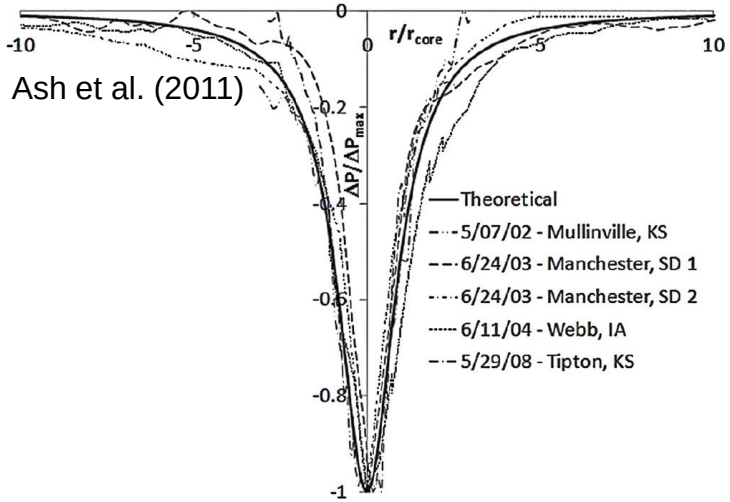


List of fluid mechanisms that could produce these observations has been narrowed down.

Radial Oscillations

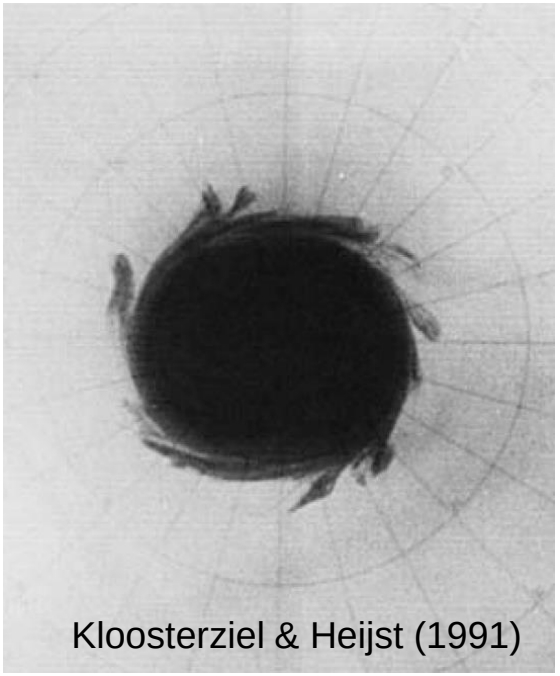


Non-equilibrium Pressure Relaxation



$$\rho\frac{Du_i}{Dt} = -\frac{\partial P}{\partial x_i} + \eta_p \frac{D}{Dt}\left(\frac{\partial P}{\partial x_i}\right) + \mu\frac{\partial^2 u_i}{\partial x_k^2} + \eta_p\left[\frac{\partial u_k}{\partial x_i}\frac{\partial P}{\partial x_k} - \frac{(\eta_v + \mu/3)}{\eta_p}\frac{\partial}{\partial x_i}\left(\frac{1}{\rho}\frac{D\rho}{Dt}\right)\right]$$

Shear Instability



Kloosterziel & Heijst (1991)

We have narrowed our list of fluid mechanisms that could produce infrasound from tornadoes.

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photo by Lori Mehmen in 2008

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