Sound & Noise 101

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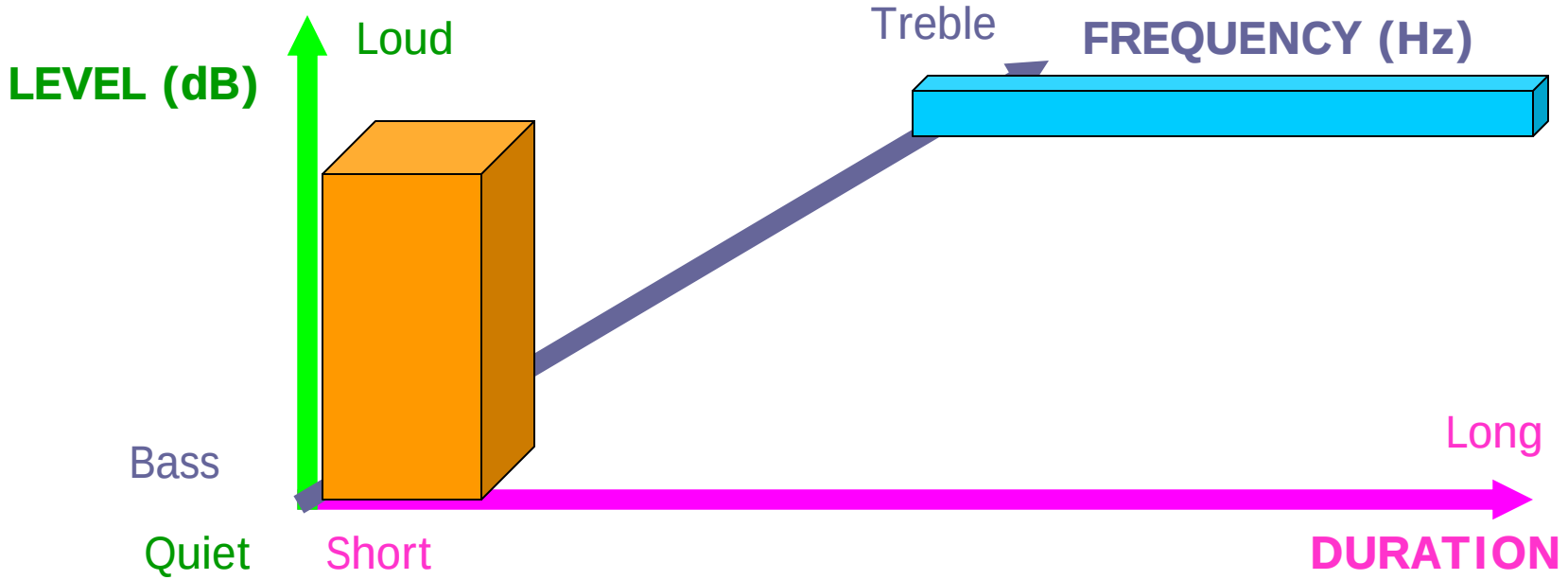
Acoustics & Noise Control
Est. 1979

Definitions

- **Level:** the “strength” of a sound. It is measured in Decibels (dB).
- **Frequency:** the “pitch” of a sound. It is measured in Hertz (Hz).
- **Spectrum**: which frequencies are in the sound. The “type” of the sound.
- **Sampling rate**: how often/how detailed we record a sound for analysis.
- **Noise:** unwanted sound.

Looking at sound in 3-D

- The **DURATION** can be expressed in seconds, minutes, or even hours
- The **LEVEL** is expressed in **decibels (dB)**
- The **FREQUENCY** is expressed in **Hertz (Hz)**



Why do some sounds sound louder than others??

- Our hearing system does no have the same **sensitivity** at all frequencies
- The frequencies contained in the sound define its **‘quality’**
- Sounds that contain few frequencies are very **‘tonal’** and they are easy for the brain to focus on because they are very simple sounds.
- Sounds that contain a lot of frequencies are very **‘neutral’** and the brain cannot identify the individual frequencies.
- Sounds that contain a very broad range of frequencies can effectively **‘mask’** other sounds with *higher* frequencies.

Does sound becomes noise when it's intermittent or modulated??

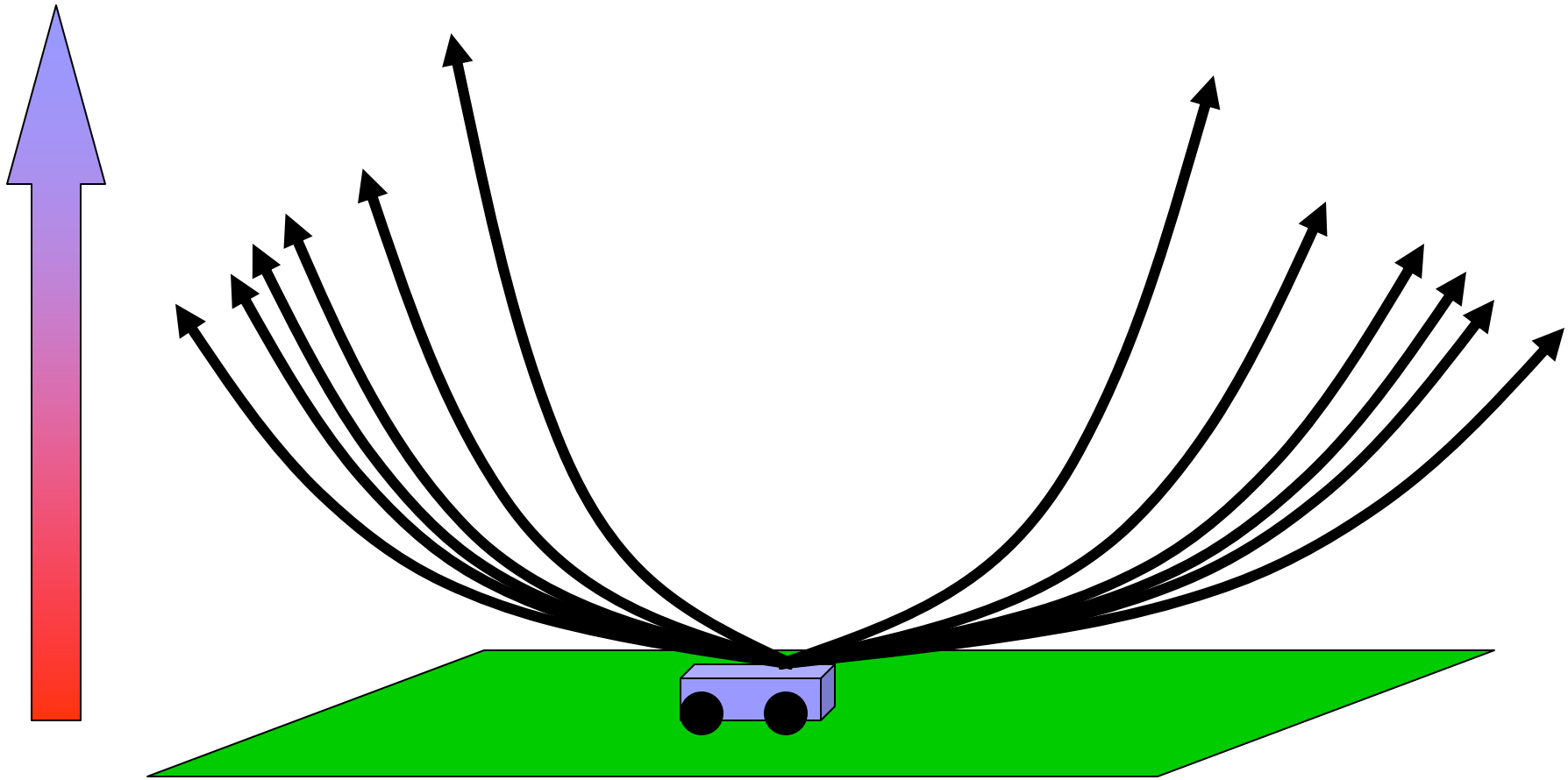
- Music is intermittent and modulated.
  - What's music to some is noise to others.
- Annoyance is **correlated** to many factors when it comes to noise…
  - The level of the sound,
  - The frequency content of the sound,
  - Opinions about the source of sound,
  - Control about the source of sound,
  - Ability to get away from the sound,
  - And **many** other factors…

Measuring sound (metrics)

- The **dB-A** is the standard way to measure noise and to base regulations upon as it attempts to evaluate **loudness** (subjective).
  - The dB-A is a poor metric for sounds that contain pure tones among other frequencies.
  - The dB-A is a poor metric for sounds that are modulated.
- The **dB-C** is a metric that can better assess the amount of bass in the noise.
- Neither the dB-A or the dB-C can account for **some** of the sound that is produced by wind turbines.
- **The measurement of sounds outdoors is strongly influenced by the presence of wind.**
- The **rate** at which the measurements are made can substantially change the results.
- Existing **standards** for the measurements of the sound created by outdoor sources are inappropriate for wind turbines.
- Existing methods to assess the sound **emission** from turbines is often of limited applicability in the context of noise pollution.

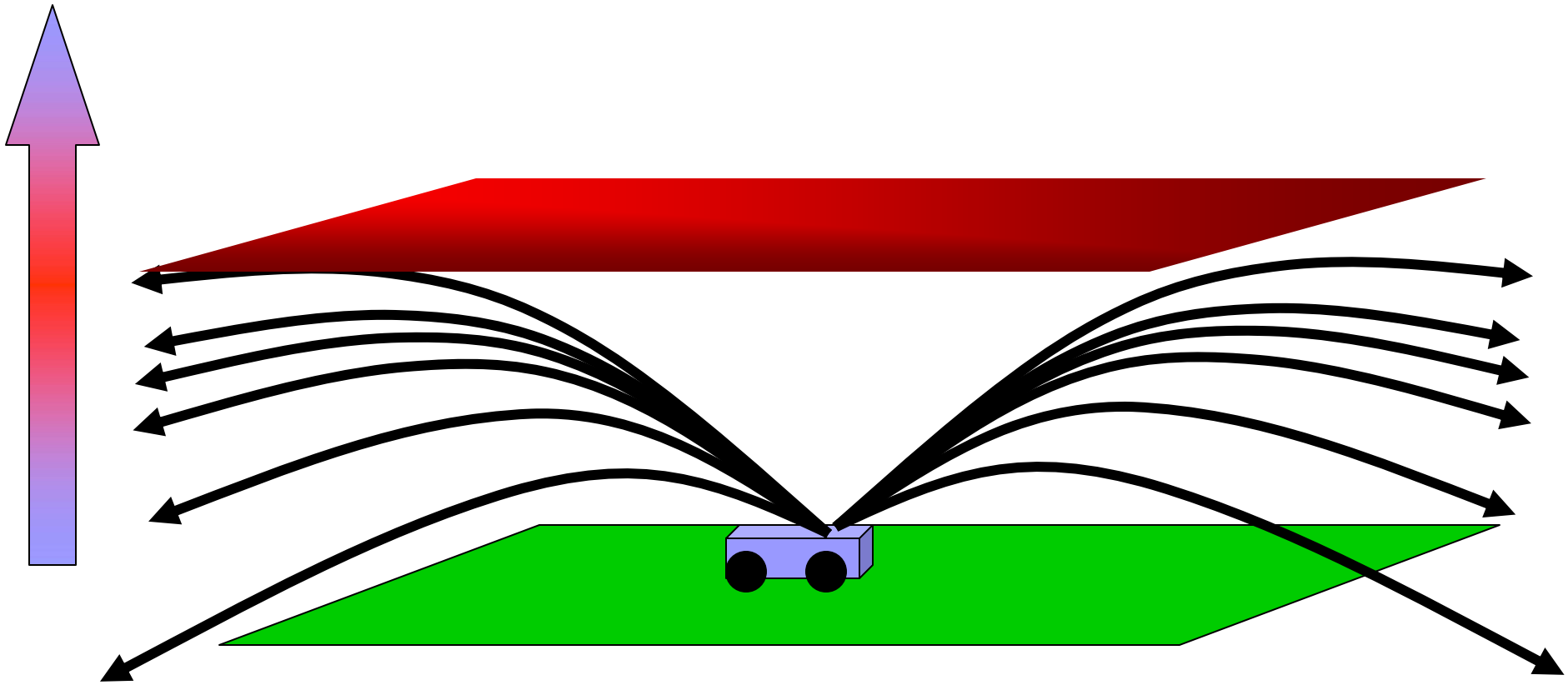
Sound Propagation Outdoors (I)

Under **normal** temperature conditions

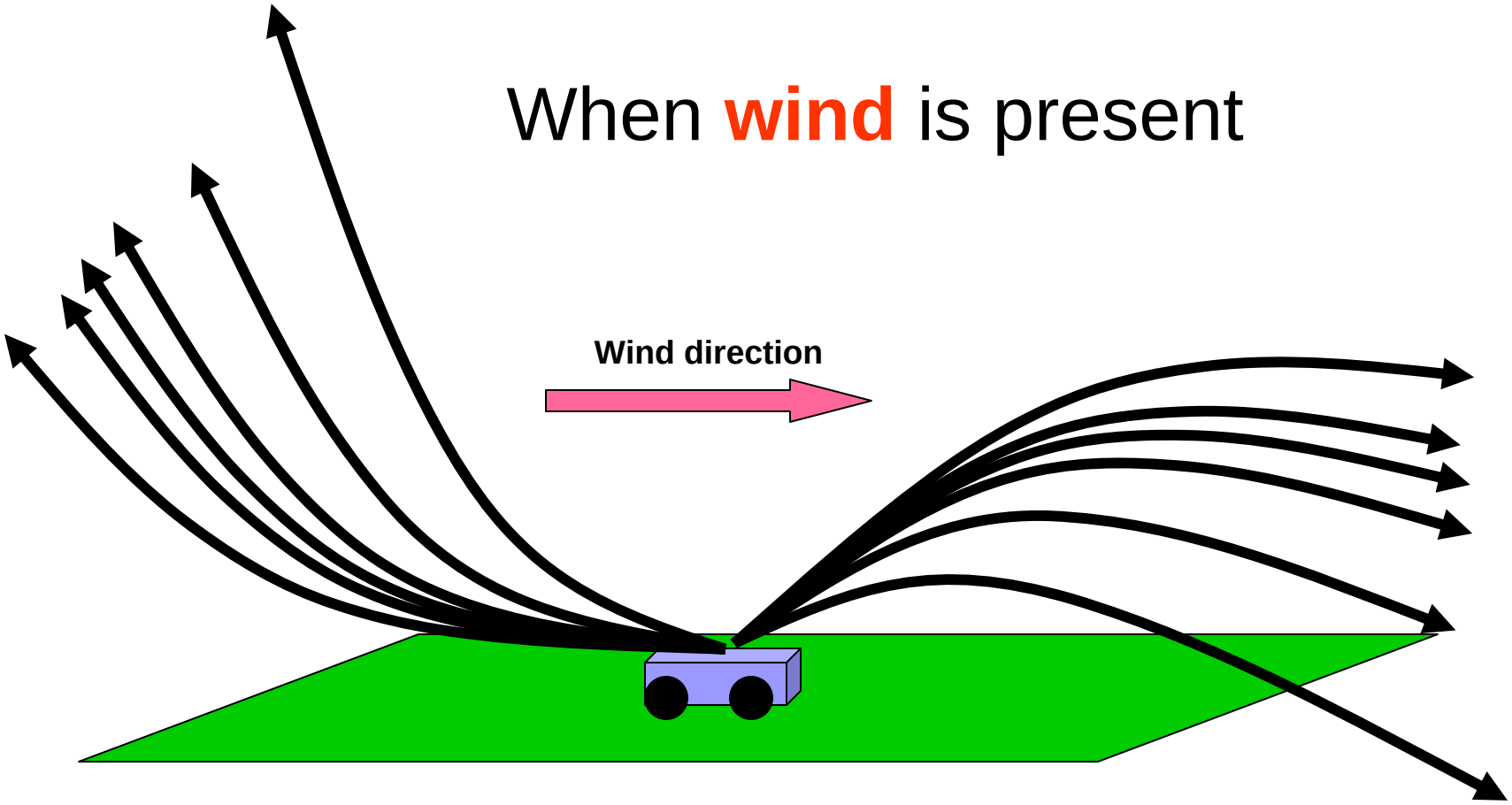


Sound Propagation Outdoor (II)

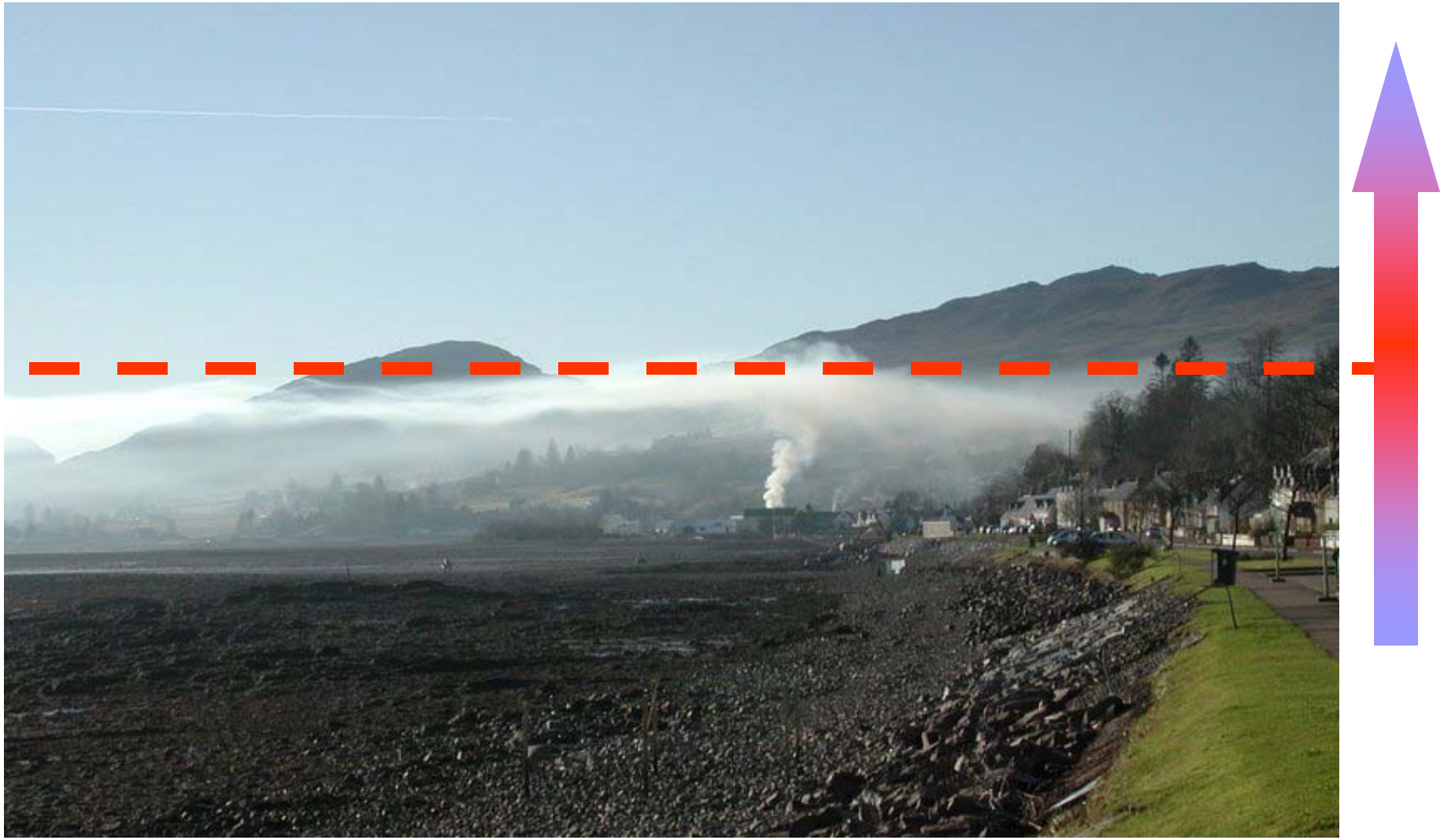
Under temperature **inversion** conditions



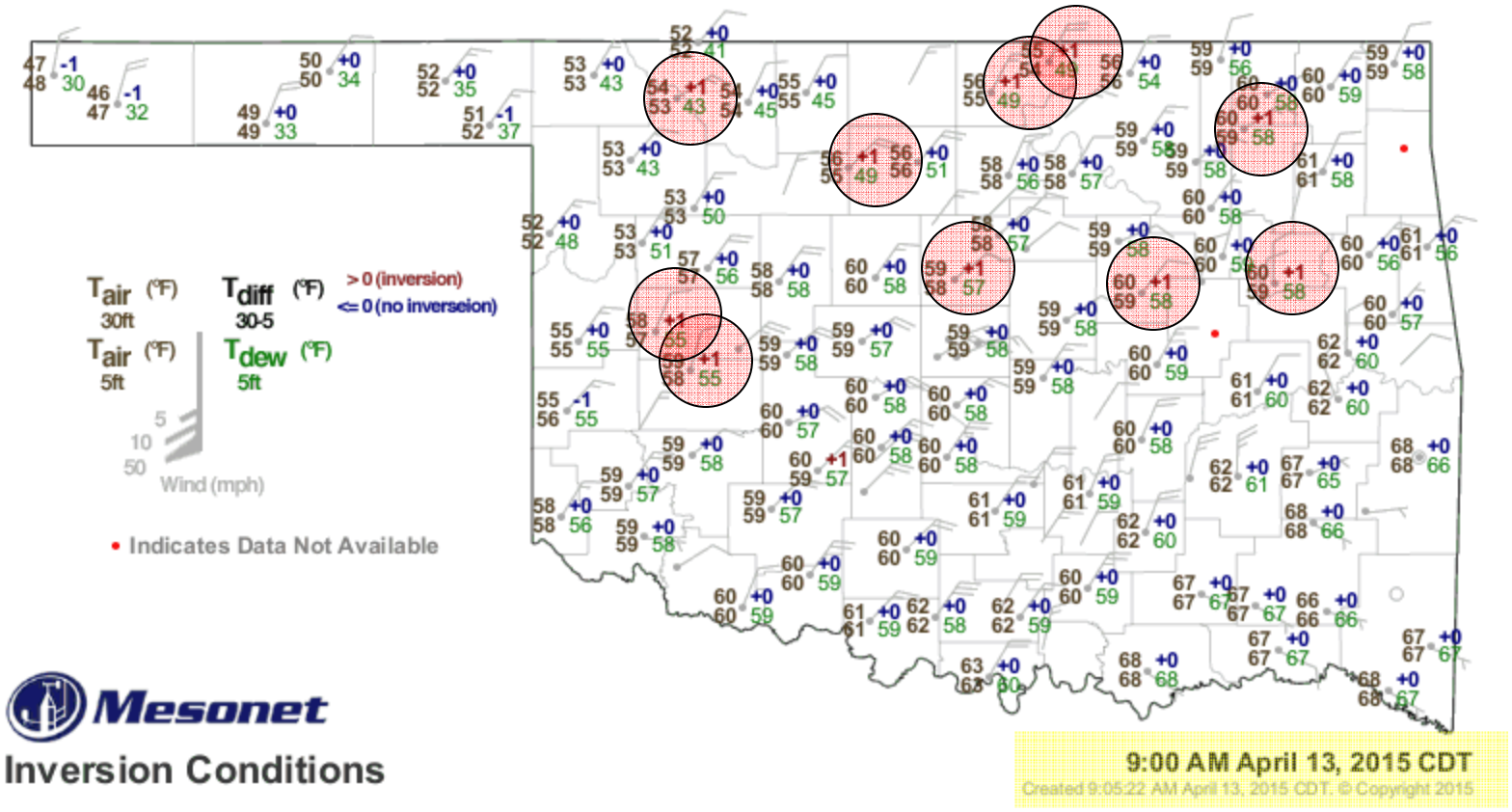
Sound Propagation Outdoor (III)



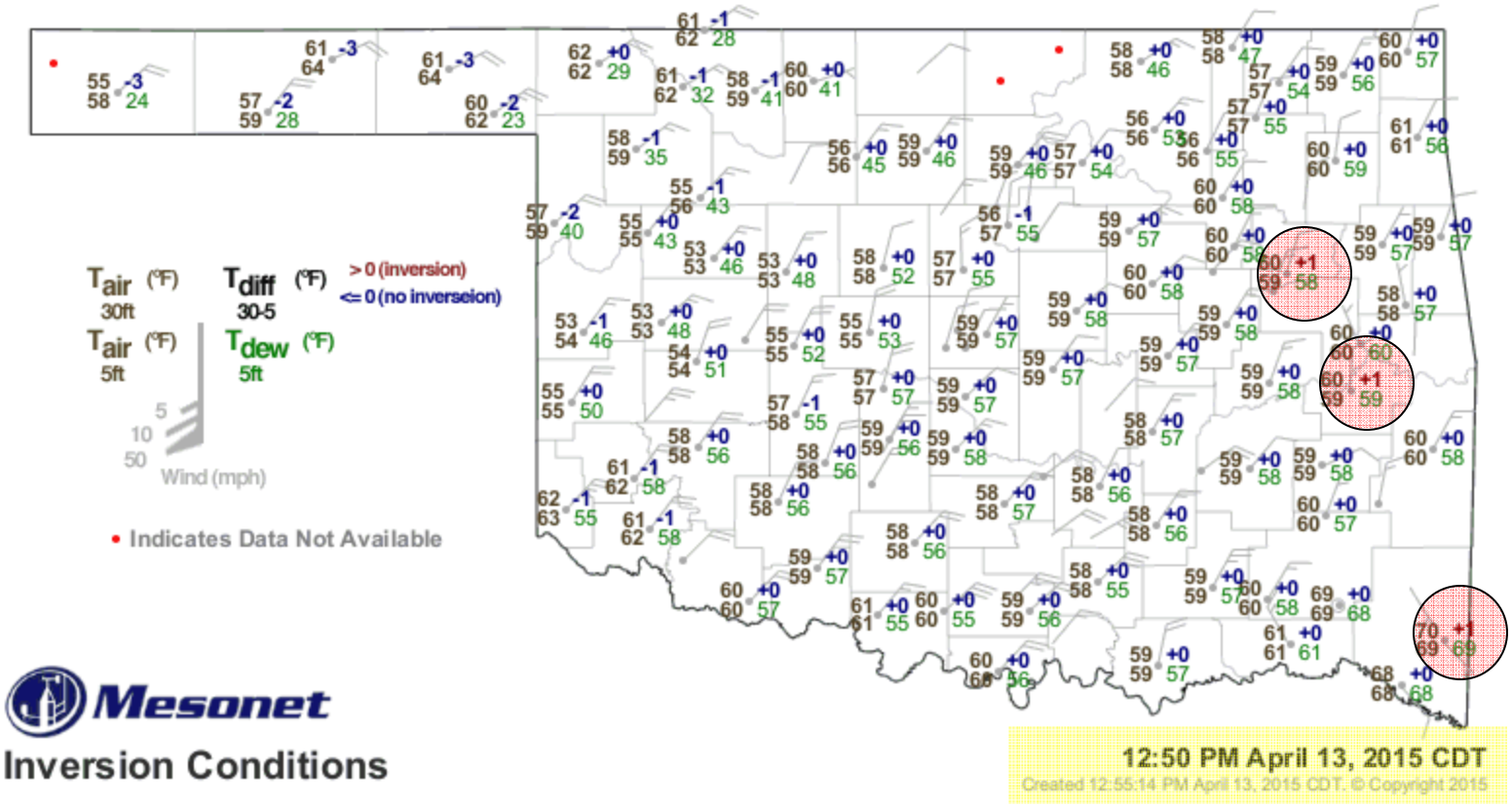
An Example of Inversion



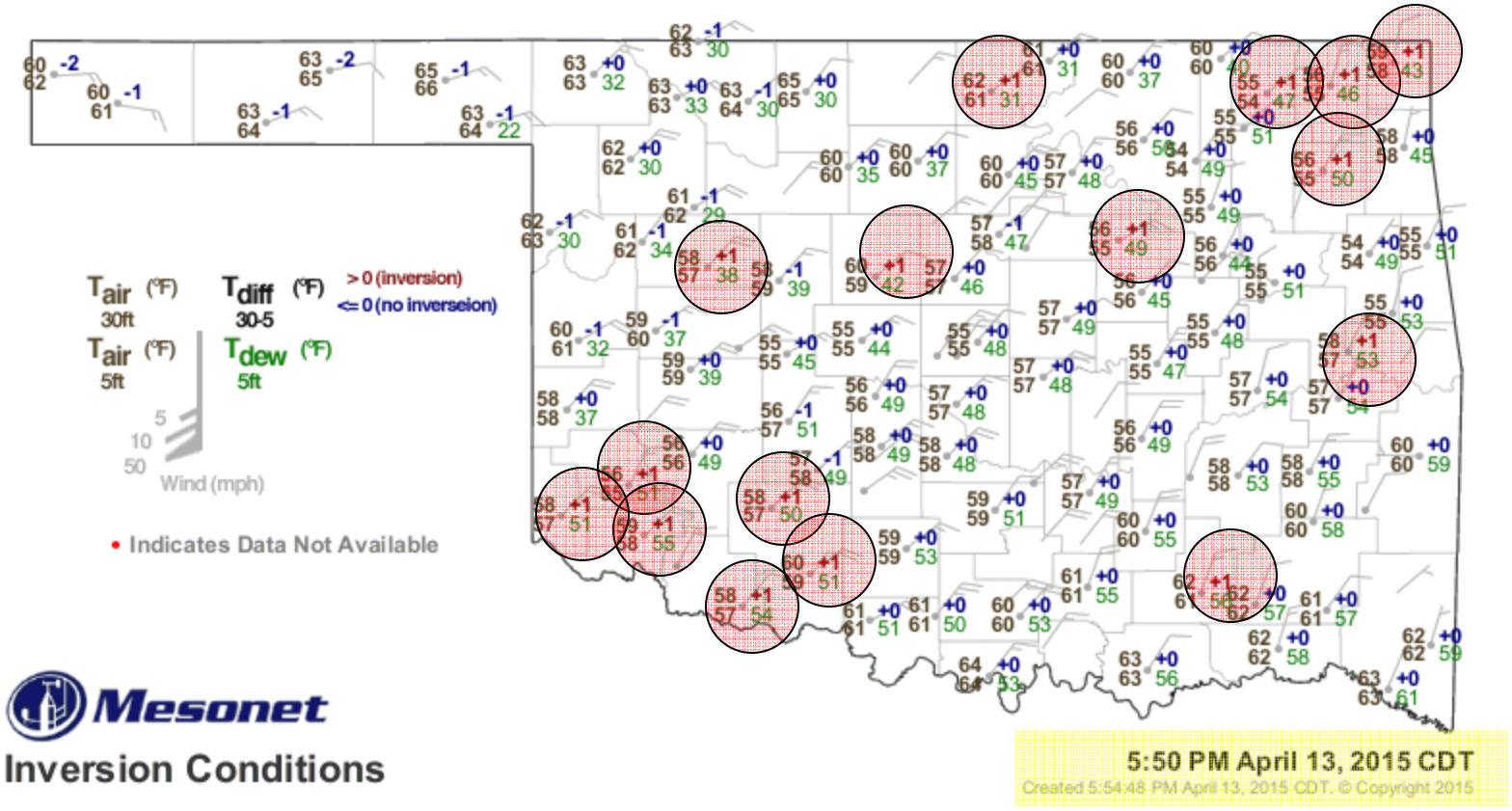
A recent scenario…



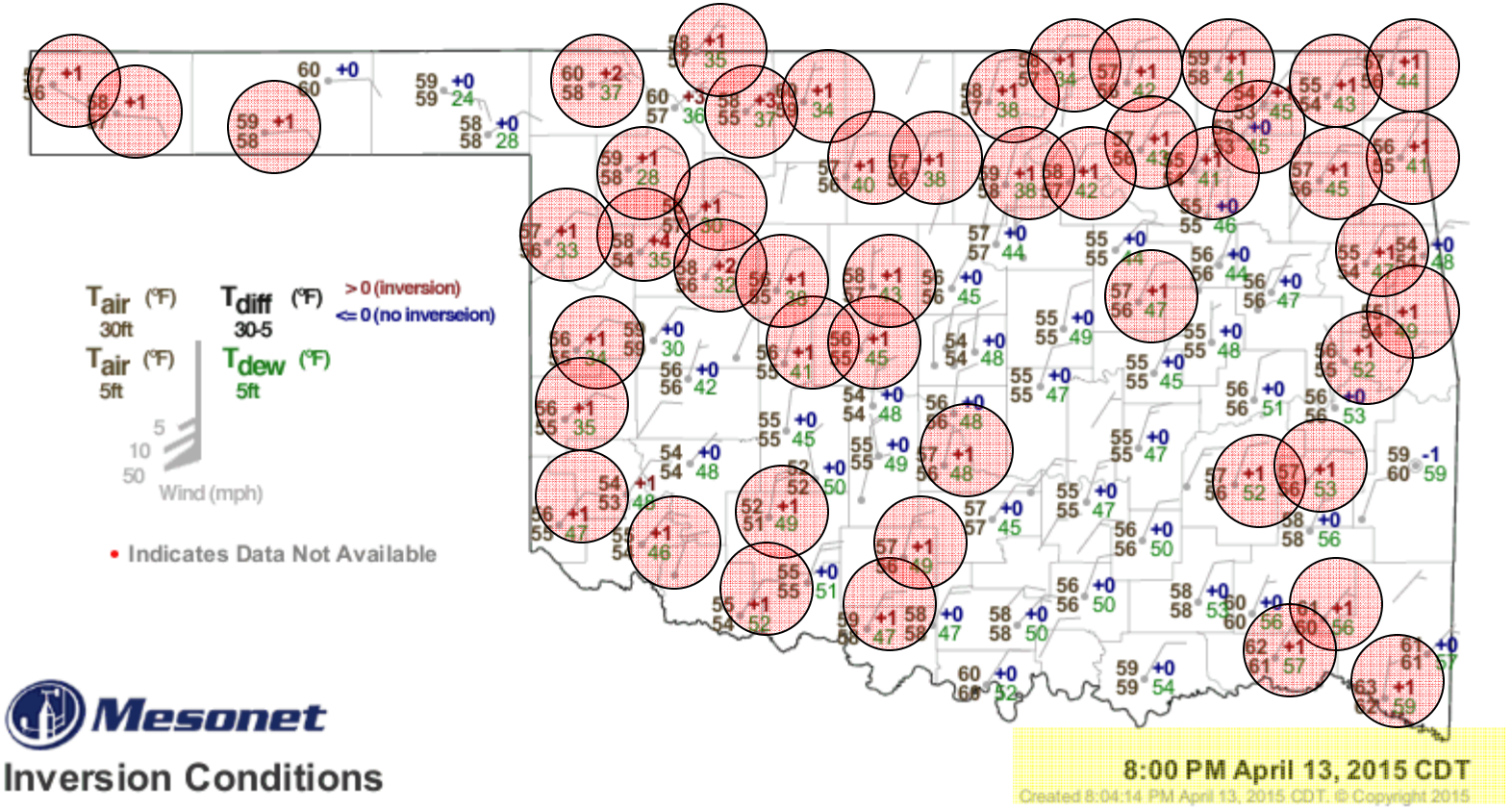
4 hours later…



5 hours later…

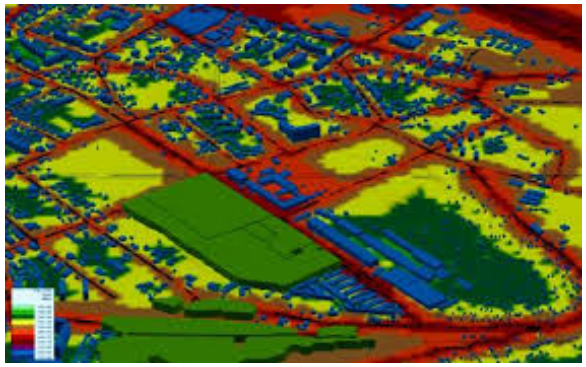


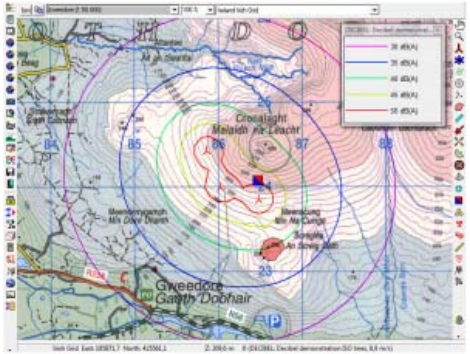
And another 2 hours later…



Facts about inversions & wind

- Sound travels much farther than normal when an inversion is present.
- Inversions most often happen during clear and stable nights as the ground cools off rapidly
  - *"Typically, temperature inversions start at dusk and break up with the sunrise because of vertical air mixing"* https://cropwatch.unl.edu/archive/-/asset_publisher/VHeSpfv0Agju/content/5-tips-for-avoiding-herbicide-drift
  - Inversions do not happen near the ground when wind speeds are high
- Outdoor noise propagation models have a difficult time dealing with **accuracy** and **practicality** when it comes to inversions and wind.





Correlation vs. causality

- **Causality:** A makes B happen
- **Correlation:** A and B can be observed to happen together:
  - Sometimes = weak correlation
  - Often = stronger correlation
  - Always = strong correlation
- Any study of causality (cause and effect) must take **all potential variables** into account.

What do we know about the sound generated by wind farms? (I)

- The sound is fairly complex:
  - The blades slicing through the air can create a **‘swish’** sound with a midrange & high frequencies.
  - The lack of smooth airflow can create some low frequency **‘thump’** sounds that also **‘pulses’** the higher frequencies.
  - The elements inside the nacelle can create some **‘whirr’** sounds with bass and midrange frequencies.
  - All of the above tend to increase with wind speed.
  - The transformer sub-station can generate some **‘hum’** tones as well as sounds from associated cooling systems.

What do we know about the sound generated by wind farms? (II)

- The sound changes with **distance**
  - The midrange and high frequency components tend to fall below the range of audibility fairly rapidly.
  - The low frequency (bass) components can still be noticeable at much greater distances.
- The absorption of the **ground** is not a factor for low-frequency sounds
- **Multiple turbines** can yield to modulation effects in the sound at some locations.
- Turbines can influence each other when it comes to the ‘smoothness’ of the air surrounding them.
- Wind turbines generate acoustic waves that are below the audible range (**infrasound**).

What do we know about the noise associated with wind farms?

- Most complaints are associated with the **‘swishing pulses’.**
- Many complaints are associated with **night-time** operations.
- **Infrasound-related** complaints are problematic to assess.
  - Interfering factors
  - Equipment limitations
  - Incorrect test methodology
- It is difficult to come up with an effective **regulation** for it.
  - Weather and other factors vary between time of complaint and time of inspection.
  - Implementing **Best Practices** can be expensive.

So what's the answer??

- Controlling factors that can be controlled?
  - Transformer sub-station noise
  - Quieter turbines.
  - Managing the operation of the turbines?

- Showing worst-case scenarios in models?
- Limiting operation during nighttime hours?
- Implementing regulations that are based on new (and potentially expensive) metrics?
- Listening to every side of the issue before coming up with questions?
- **That's what I am going to do ☺**

Thanks!