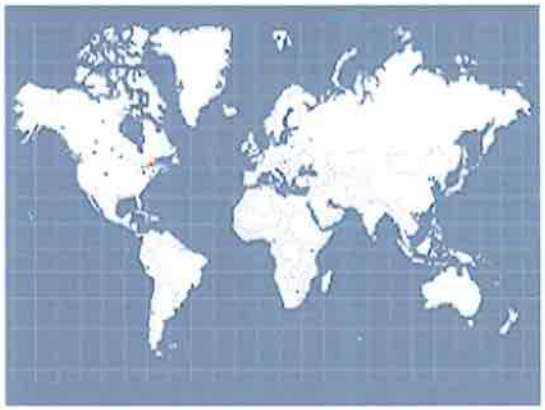


SNC·LAVALIN

Field Measurement Challenges for Wind Turbines Relating to Audible Noise

Emanuel Mouratidis

Air & Waste Management Association
Ontario Section Annual Conference
October 6, 2010.

OVERVIEW

- **Perceived audible noise emissions.**
- **Real sound measurement challenges.**
- **Industry needs - uniform field measurement protocol:**
  1. Acoustic Audits
  2. 'Complaint' Based Investigations

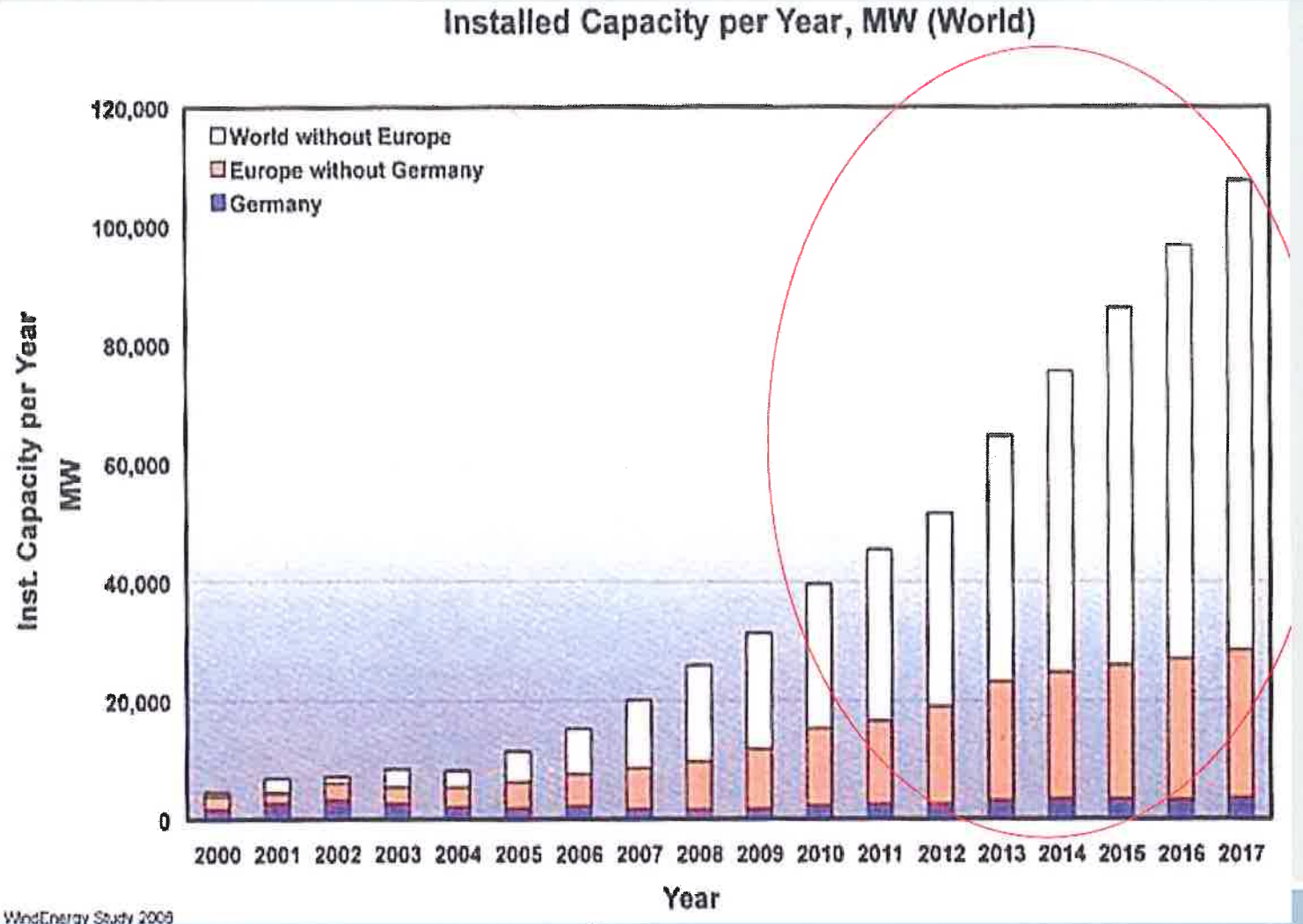



WIND POWER IN ONTARIO

- **Major changes over the past 10-years:**
  - Industry interest;
  - Equipment performance and capability;
  - Stakeholder awareness; and,
  - News media coverage.

- **Production is in a <u>growth</u> mode.**

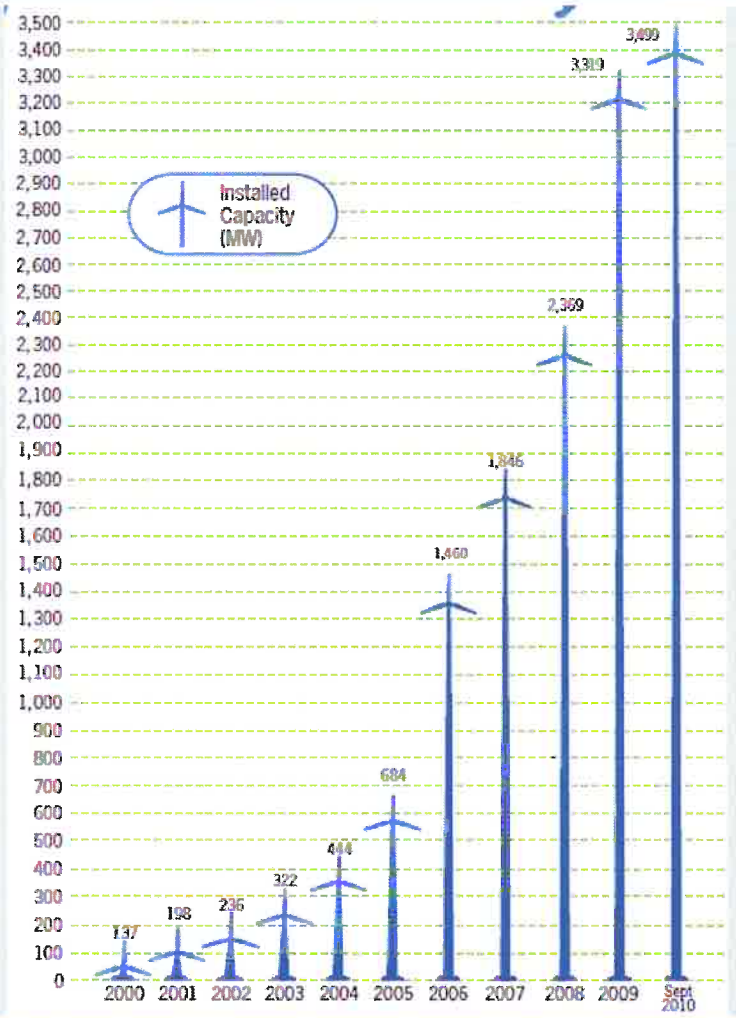
WIND POWER – A GROWTH INDUSTRY



Source: WindEnergy Study 2009

WIND POWER – A GROWTH INDUSTRY

- Approximately 1,500 MW <u>installed</u> in Ontario (2010).
- Majority 'large' turbines (2 - 2.5 MW).



Source: CanWEA, 2010.

PERCEIVED NOISE EMISSIONS

- **Noise may be defined as 'unwanted sound'.**
- **Residents in close proximity to wind turbines may report a unique set of noise descriptors:**
  - Too Loud;
  - Pulsing / Swoosh;
  - Whine;
  - Ringing;
  - Throbbing;
  - …

WIND FARM ACOUSTICS

- Post noise modelling and field commissioning, an acoustic audit may be necessary.
- Most wind farms are within rural areas, with very few turbines near industrial areas and bodies of water (for now).
- No two wind farms are the same.
- Within any wind farm, no two receptors are the same.

ACOUSTICS *101*

- **Noise impact determined by the unique Source-Path-Receiver relationship.**
- **Source:**
  - Hubs - 80 - 100 m above the ground;
  - Similar blade construction;
  - Different blade profiles;
  - Gear box vs. direct drive.
- **Path:**
  - Terrain (barriers, ground effects, surface waves, etc.);
  - Temperature;
  - Wind;
- **Receiver:**
  - Height;
  - Orientation;
  - Construction; and,
  - Land use.

(1) ACOUSTIC AUDIT – BASIC REQUIREMENTS

- **Need to determine worst case noise receptors, considering many factors:**
  - Proximity;
  - Shielding;
  - Potential shadow zones; and,
  - Other factors.
- **Complete during potential worst case operating conditions:**
  - Scheduling (wind farm and surrounding operations);
  - Time of day (temperature and wind gradients); and,
  - Seasonal.
- **Need to follow a well-defined test plan that is accepted as industry's best practice.**

(2)COMPLAINT STUDY – ADVANCED REQUIREMENTS

- **Complaint based study is the acoustic audit <u>plus</u> a few key tasks:**
  - Assess the nature of the receptor complaints:
    - → Based on recognized methods, such as: *ISO 15666 - Acoustics — Assessment of noise annoyance by means of social and socio-acoustic surveys*
  - Confirm the condition(s) that may relate to the complaint;
  - Develop comprehensive test plan in consultation with stakeholders; and,
  - Although key measurement points have been identified, may include other non-complaint receptors.

INSTRUMENTATION

- **<u>Minimum</u> Instrumentation Requirements:**
  - Sound level meters;
    - → Type 1 precision (2-channel preferred)
  - Environmental protection kits;
  - SLMs w/ remote monitoring capabilities;
  - Portable weather stations; and,
  - Audio recorders.

Source: LarsonDavis

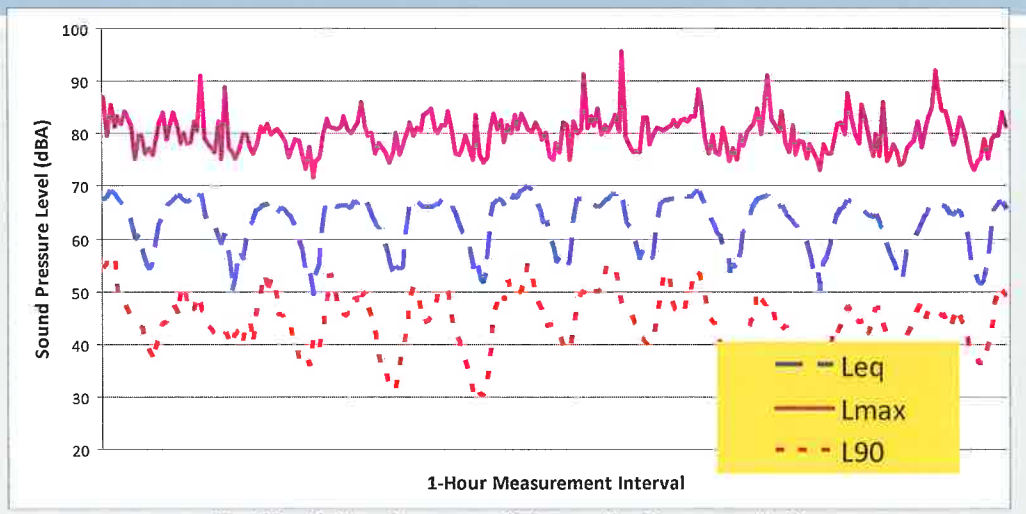
DATA COLLECTION

Source: www,gstatic.com

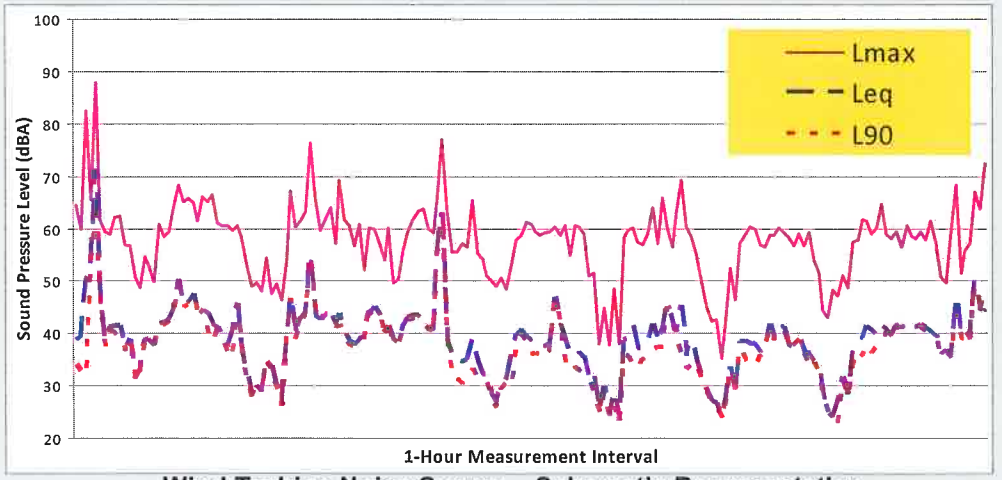
- Simultaneous sound, wind and temperature data collection at multiple points within the study area.
- Measurement number, type and sample time must address the nature of the sound and an acceptable level of confidence.
- Duration – several days (not hours).

TYPICAL NOISE SURVEYS

- Collect and evaluate the equivalent sound pressure level (Leq).
- Various survey types may appear to be similar.
- Upon careful examination, wind turbine emissions are unique.



Traffic Noise Survey – Schematic Representation



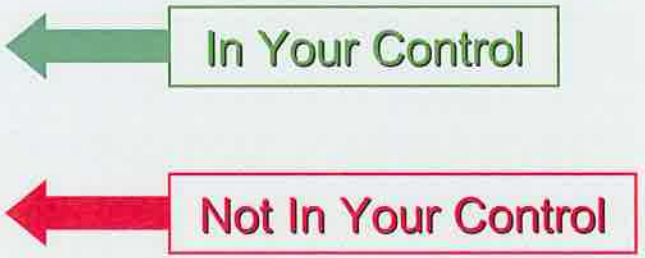
Wind Turbine Noise Survey – Schematic Representation

NOISE SURVEYS – REAL-LIFE ISSUES

- **Two main challenges associated with a noise survey at a wind farm:**

1) **Physical Constraints (location, instrumentation); and,**

2) **Environmental Constraints.**

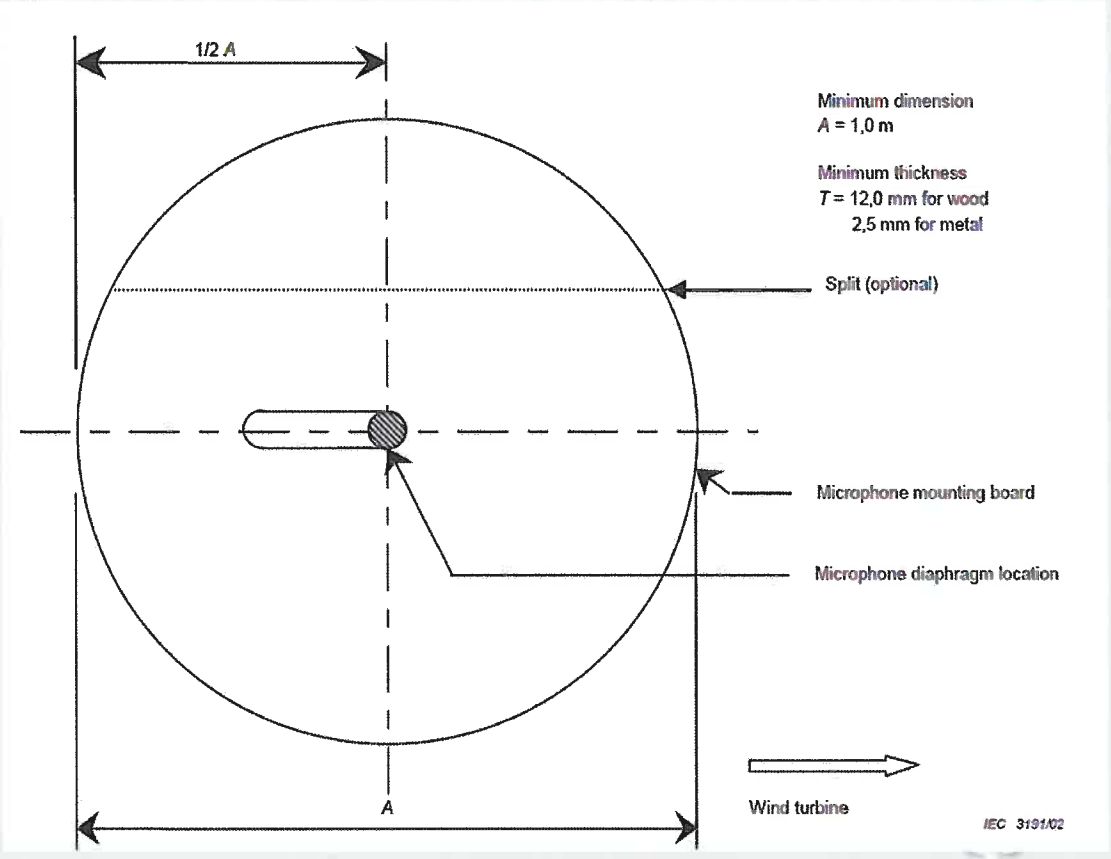


WIND INDUCED MICROPHONE NOISE

- **Typical microphone screens allow 40 dBA measurements up to 4 m/s (15 km/hr).**
- **Wind turbine measurements demand 30 dBA max mic noise up to 6 m/s.**
- **Available wind induced (pseudo) noise reduction techniques include:**
  - Two microphone cross correlation.
  - Mounting the microphone on a reflecting board.
  - Directional microphone.
  - Large secondary wind screen.

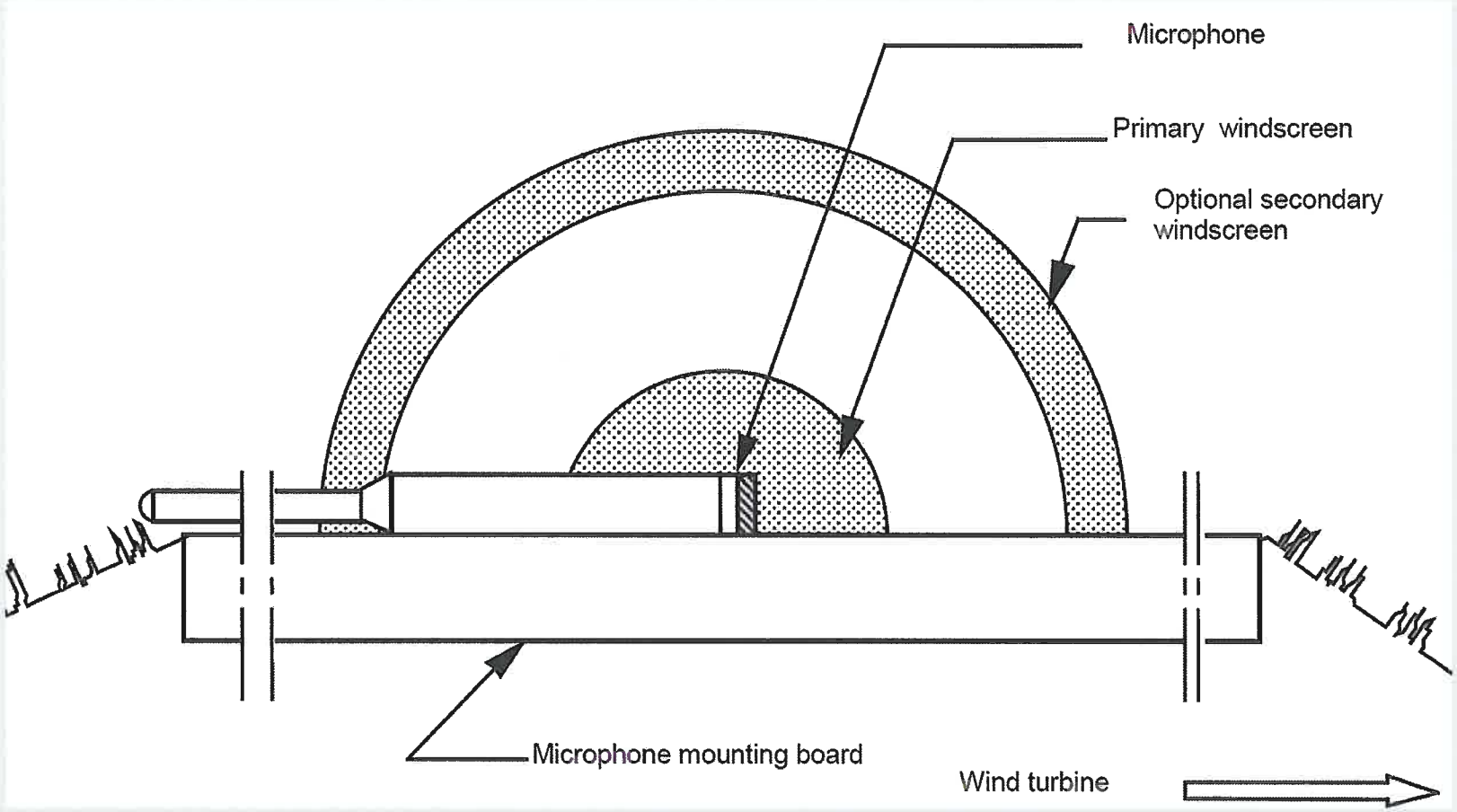
IMPROVED MICROPHONE SIGNAL

- **Microphone on a reflecting board:**



Source: IEC 61400-11 (2002).

IMPROVED MICROPHONE SIGNAL

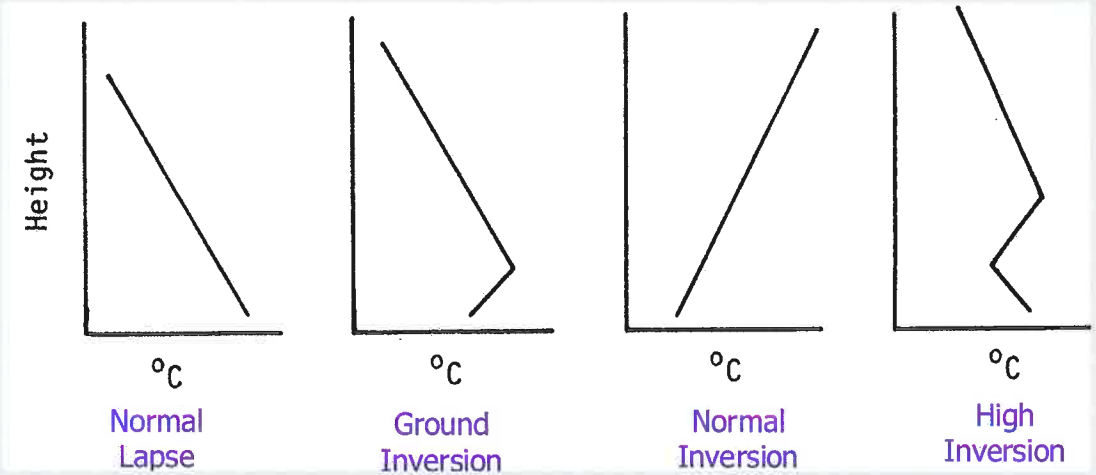


Source: IEC 61400-11 (2002).

ATMOSPHERIC CONSIDERATIONS

- **Daytime:**
  - Temperature decreases with height;
  - Warming air rises, carrying sound aloft;
  - Creating turbulence that scatters the turbine sound.

Source:www.secondwind.com

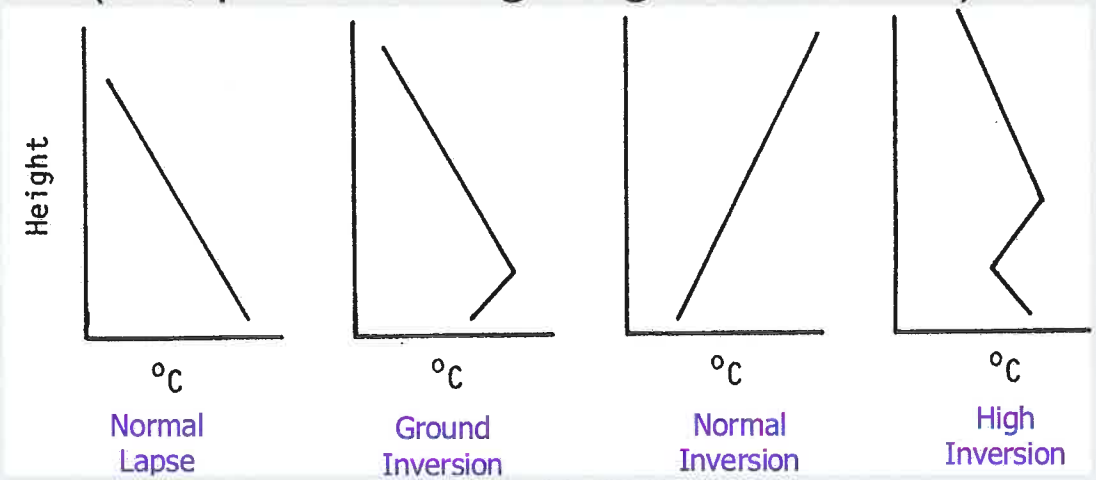


Source: Reynolds (1991)

ATMOSPHERIC CONSIDERATIONS

- **Night time:**
  - Temperature stabilizes, then increases with height (normal inversion);
  - Relatively high winds at turbine height and very little or no wind at ground level (i.e., potential high signal-to-noise).

Source:www.secondwind.com



Source: Reynolds (1991)

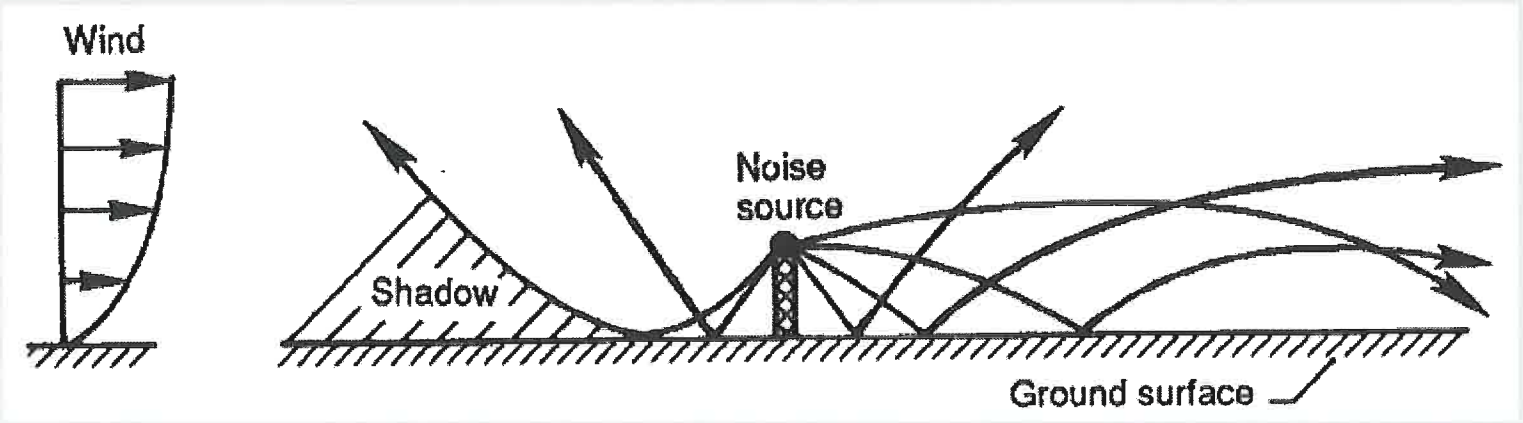
ATMOSPHERIC CONSIDERATIONS

- Inversion layers may form above the height of turbines;
- Reflect some of the sound toward the ground (channel effect).

Source: www.en.wikipedia.org/wiki/File:SmokeCeilingInLochcarron.

ATMOSPHERIC CONSIDERATIONS

- On the upwind side of the turbine, acoustic rays tend to bend upward.
- Radiation pattern creates upwind Shadow Zone.
- Receptors in the Zone may experience bias results – due to wind speed/direction.



Source: Wind Turbine Acoustics, H. Hubbard, NASA, 1990.

TERRAIN

- Influences ground absorption, reflection and refraction.
- In mountainous areas, terrain induced changes on the wind profile may influence the stability-related impacts.
- Ridgelines may provide beneficial shielding or no shielding.
- Gently sloping terrain may increase sound levels slightly with increasing distance, due to increased ground angles that cause sounds to combine.
- Each location should be studied carefully.

GROUND SURFACE

- **Acoustically 'soft' surfaces attenuate sound more than 'hard' surfaces;**
- **Forest - density and age;**
- **Snow covered vs. no snow;**
- **Bodies of water**
  - Attenuation varies with water temperature; and,
  - Atmospheric stability may be more severe in the winter-spring period.

WORST CASE NOISE RECEPTOR?

- **Many factors determine the worst case receptor;**
- **Site evaluation is necessary during the test planning and instrumentation set-up.**
- **Factors form an integral part of the post-processing of the results.**

MOE ACOUSTIC AUDITS

- Confirm that the facility does not exceed MOE limits at qualified receptors (as per MOE NPC-205 or NPC-232).
- Based on the worst-case 1-hour equivalent sound level.
- Measurement based audit – most of the time.
- In some situations (e.g., receptors are impacted by noise from other facilities that are not related), it may be necessary to perform some combination of measurements and modelling in order to provide an acceptable audit.
- MOE may scrutinize the measurements and methodologies used in an audit.

MOE ACOUSTIC AUDITS – WIND FARMS

- **Some possible acoustic audit requirements unique to a wind farm:**
  - Conditions that define a worst case noise impact (source-path-receiver);
  - Methodology to establish acceptable signal-to-noise;
  - Instrumentation specifications;
  - Siting of instrumentation at the site; and,
  - Comprehensive data collection (w/ statistical and uncertainty analysis).

ACOUSTIC DATA ANALYSIS

- **Now that we have this data – what next?**

- **<u>Many</u> analysis tools available:**
  - Overall background noise (Leq; Lmax; L90; etc.);
  - Tones (prominence ratio);
  - Fluctuating noise (Lmax – Leq);
  - Low frequency noise (dBA – dBC);
  - Vibration (noise induced);
  - Others.

ACOUSTIC AUDIT – QUALITY REVIEW

- **Complete acoustic audit should include a quality review, in order to verify:**
  - Did the measurement locations represent the worst case emissions?
  - What is the measurement repeatability under apparent equivalent background conditions?
  - What is the measurement repeatability under apparent equivalent wind turbine operating conditions?
  - What is the measurement reproducibility among different turbines under apparent equivalent operating and background conditions?
  - List non-acoustic factors that may impact the results.
- **Statistical analysis may be based on the available ISO and ANSI standards for outdoor sound measurements.**

FUTURE FOR WIND FARM MEASUREMENTS

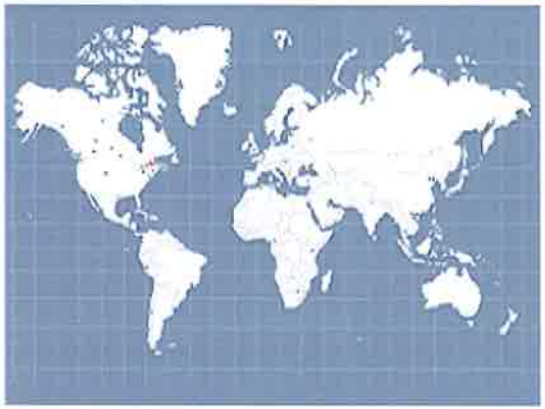
- **In Ontario, MOE is developing a *"measurement procedure to assess noise compliance of existing wind farms with the applicable sound level limits"* (MOE RFP No.OSS-078695, 2010).**

- **Instrumentation capabilities continue to improve, including:**
  - reduced size and cost;
  - increased storage capacities; and,
  - remote measurement and control.

- **More 'real data' will become available.**

FIELD MEASUREMENT CHALLENGES FOR WIND TURBINE NOISE - SUMMARY

- **Wind power is growing – rapidly.**
- **Not your 'average' acoustic audit.**
- **Two levels of complexity:**
  1. Audit – regulatory compliance; and,
  2. Complaint based – identify and resolve.
- **Planning and experience is key.**



THANK YOU

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