Influence of vertical temperature gradients on outdoor sound propagation in a narrow valley

Michel Vuillermoz, Filippo Berlier, Christian Tartin, Christian Tibone, Daniele Crea, Marco Cappio Borlino
Objectives

- Correlation between vertical temperature gradients and environmental noise, quantification of this correlation
- Analysis on empirical data collected by ARPA vda (2006 / 2012)
- Definition of a method to characterize temperature profiles
- Monitoring noise level related to different meteorological conditions
Case study
Thermal inversion

Aosta city
12 January 2012

Standard temperature profile
Phenomenon

\[
\begin{align*}
\frac{\sin \theta_1}{\sin \theta_2} &= \frac{c_1}{c_2} \\
c &= \sqrt{kRT}
\end{align*}
\]
Thermometers location

Thermometers profile line

Steel factory
Sound-level meters location

Steel factory

North hillside

City 1, City 2

Bottom of the valley

South hillside

Highest point
Profiles description method

\[ c_{ad} = \sqrt{kRT(z)} \approx \frac{1}{2} (kR) \]

\[ \approx c_0 + \frac{(kR)}{c_0} (T(z) - T_0) \approx \]

\[ \approx c_0 + a \ln \left( 1 + \frac{z}{z_0} \right) + b \cdot z \]

\[ a: \text{bending} \]

\[ b: \text{slope} \]
Correlation: Thermal profiles - coefficients

Coefficient a

Coefficient b
Correlation Thermal profiles - coefficients

Thermal inversion on the whole profile = 2.18 %

Thermal inversion partially on the profile = 18.27 %

Coefficient distribution

Coefficient a (Bending)

Coefficient b (Gradient)
Thermal inversion situations

<table>
<thead>
<tr>
<th>Altitude [m]</th>
<th>Time [hours]</th>
<th>Frequency [%]</th>
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</thead>
<tbody>
<tr>
<td>1150</td>
<td>2</td>
<td>55</td>
</tr>
<tr>
<td>1100</td>
<td>4</td>
<td>50</td>
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<tr>
<td>1050</td>
<td>6</td>
<td>45</td>
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<tr>
<td>1000</td>
<td>8</td>
<td>40</td>
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<tr>
<td>950</td>
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<td>900</td>
<td>12</td>
<td>30</td>
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<td>850</td>
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<td>800</td>
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<td>750</td>
<td>18</td>
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<td>700</td>
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<tr>
<td>600</td>
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Thermal inversion rate

Frequency [%]
**Reasons for the classification**

- Create a clear correlation between temperature profiles and noise levels (similar profiles ↔ average noise)
- Time and meteorological conditions imposed
South hillside L95 [dBA] – 200 [m] above the source

- Standard profile
- Gradient > 1.5 °C/100 m
- Thermal inversion
- Huge gradient > 4 °C/100 m
South hillside L95 [dBA] – 200 [m] above the source

- Standard profile
- Gradient > 1.5 °C/100 m
- Thermal inversion
- Huge gradient > 4 °C/100 m

Noise level [dBA]

Altitude [m]

Temperature °C
South hillside L95 [dBA] – 200 [m] above the source

Noise level [dBA]

Standard profile  Gradient > 1,5 °C/100 m  Thermal inversion  Huge gradient > 4 °C/100 m

Altitude [m]
South hillside L95 [dBA] – 200 [m] above the source

- **Standard profile**
- **Gradient > 1.5 °C/100 m**
- **Thermal inversion**
- **Huge gradient > 4 °C/100 m**

![Graph showing noise level vs. temperature and altitude](image)
South hillside L95 [dBA] – 200 [m] above the source

- Standard profile
- Gradient > 1.5 °C/100 m
- Thermal inversion
- Huge gradient > 4 °C/100 m
Bottom of the valley L95 [dBA]

Same altitude of the source

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<td>48</td>
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<td>58</td>
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Bottom of the valley L95 [dBA]

Same altitude of the source

- Standard profile
- Gradient > 1.5 °C/100 m
- Thermal inversion
Bottom of the valley L95 [dBA]

Same altitude of

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Temperatura °C

Quota [m]
Bottom of the valley L95 [dBA]

Same altitude of the source

Standard profile
Gradient > 1,5 °C/100 m
Thermal inversion
City 1 L95 [dBA]

Same altitude of the source

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Conclusions

- Thermal inversion is a common phenomenon in Aosta Valley
- Noise increase up to 10 dB
- Increases are strongly influenced by the position and the altitude of the receptor
- The noise level increase could be a negative factor on the disturbance on population, especially during the night
Thank you for your attention