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Meteorological Institute
*Ministry of Infrastructure
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A Three-Dimensional Array for the Study of Infrasound Propagation through the Atmospheric Boundary Layer

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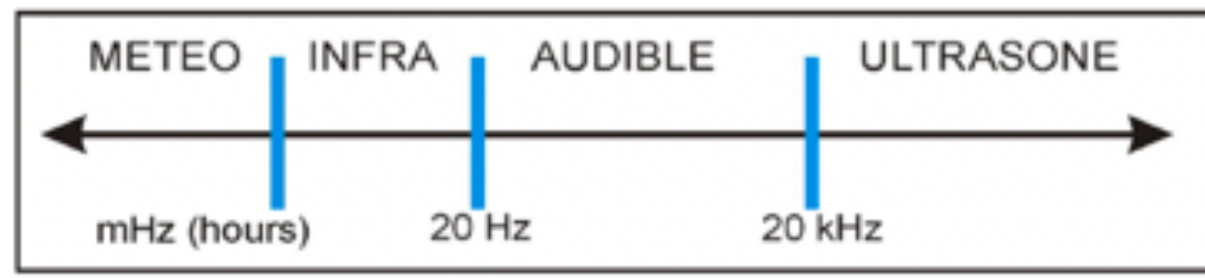
Infrasound - Low Frequency Sound

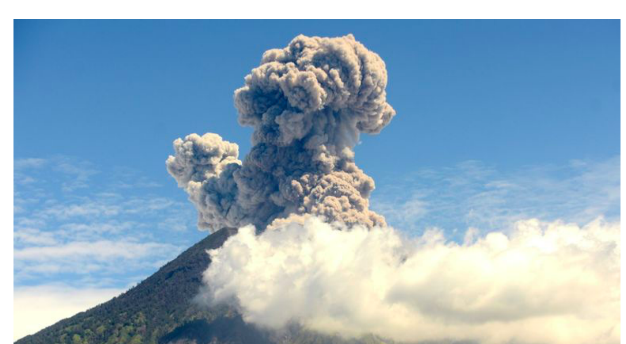
- Sound waves with frequencies below 20 Hz
- Low attenuation
- Propagating over large distances



Sources:

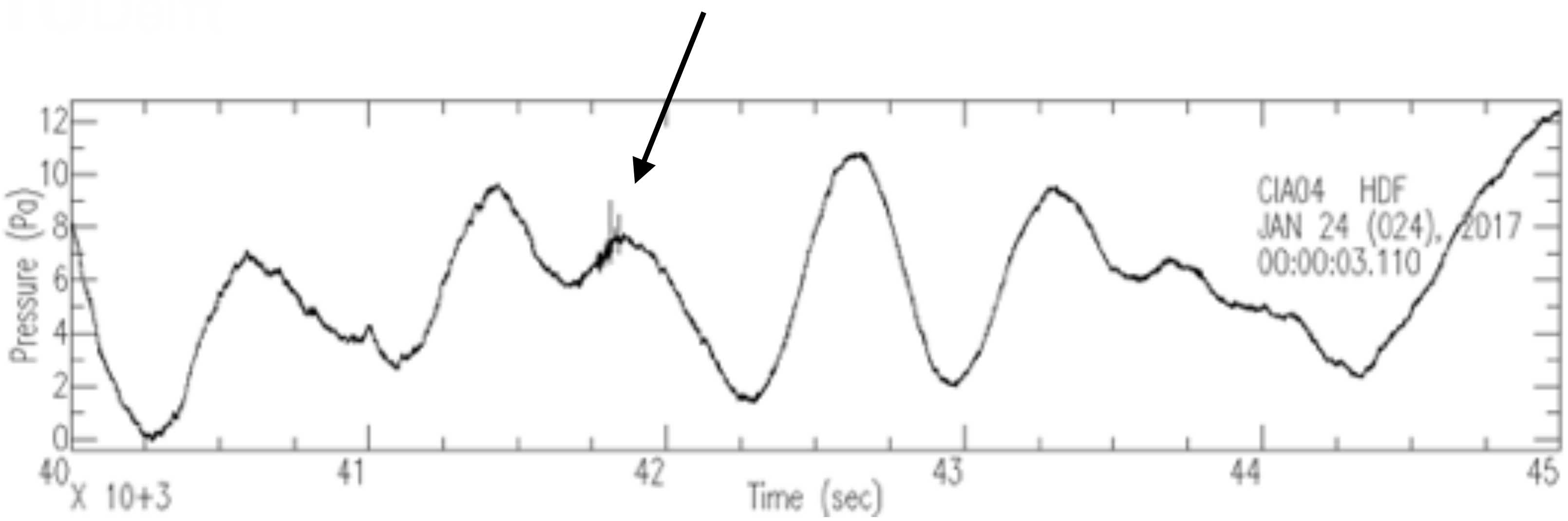
- Natural sources, e.g. volcanic eruption, avalanches, meteors, aurora, etc.
- Anthropogenic sources: (nuclear) explosions, sonic boom



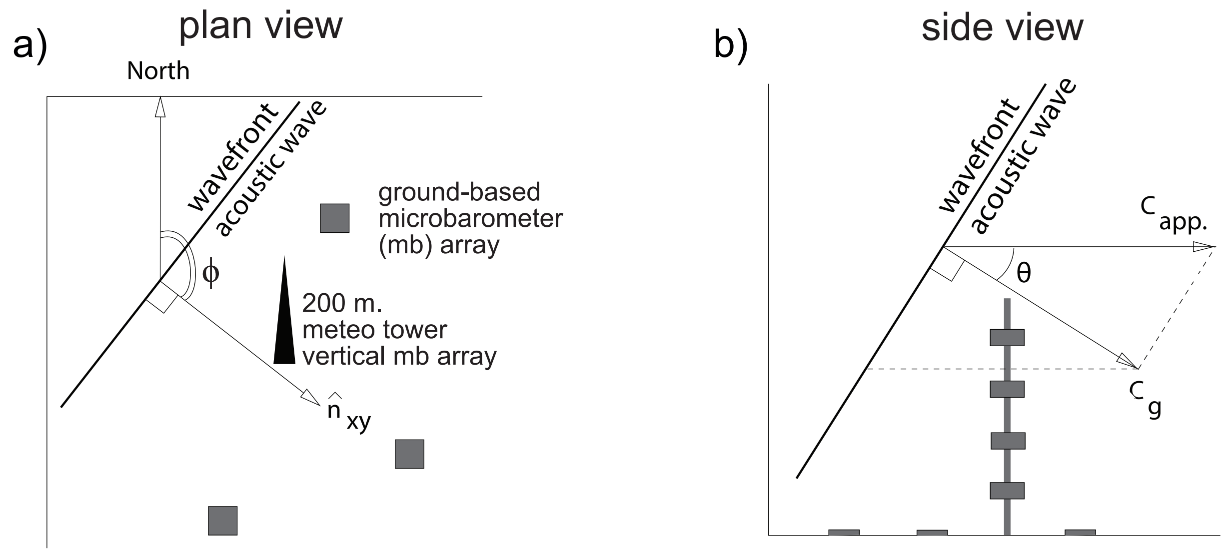



Microbarometers

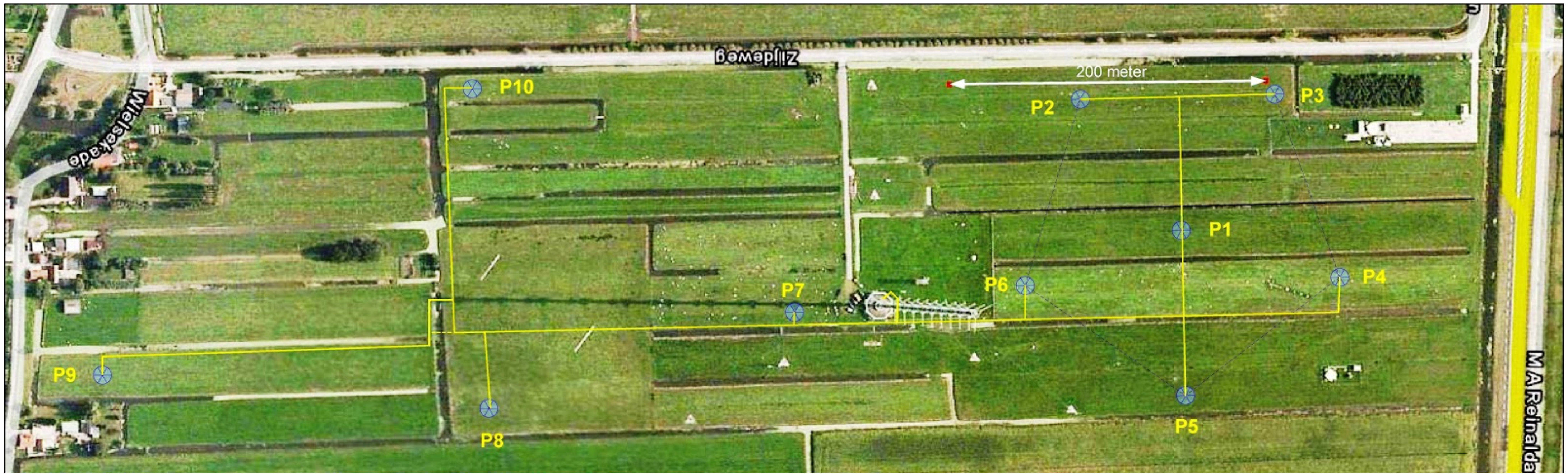
- Sensitive to both gravity waves and infrasound
- Sensitive to variations from several 10^2 Pa to 10^{-2} Pa.
- High resolution pressure measurements



Microbarometers



- Microbarometers generally ground-based
- Unique three-dimensional Infrasound Array at Cabauw
- Sensitivity to atmosphere



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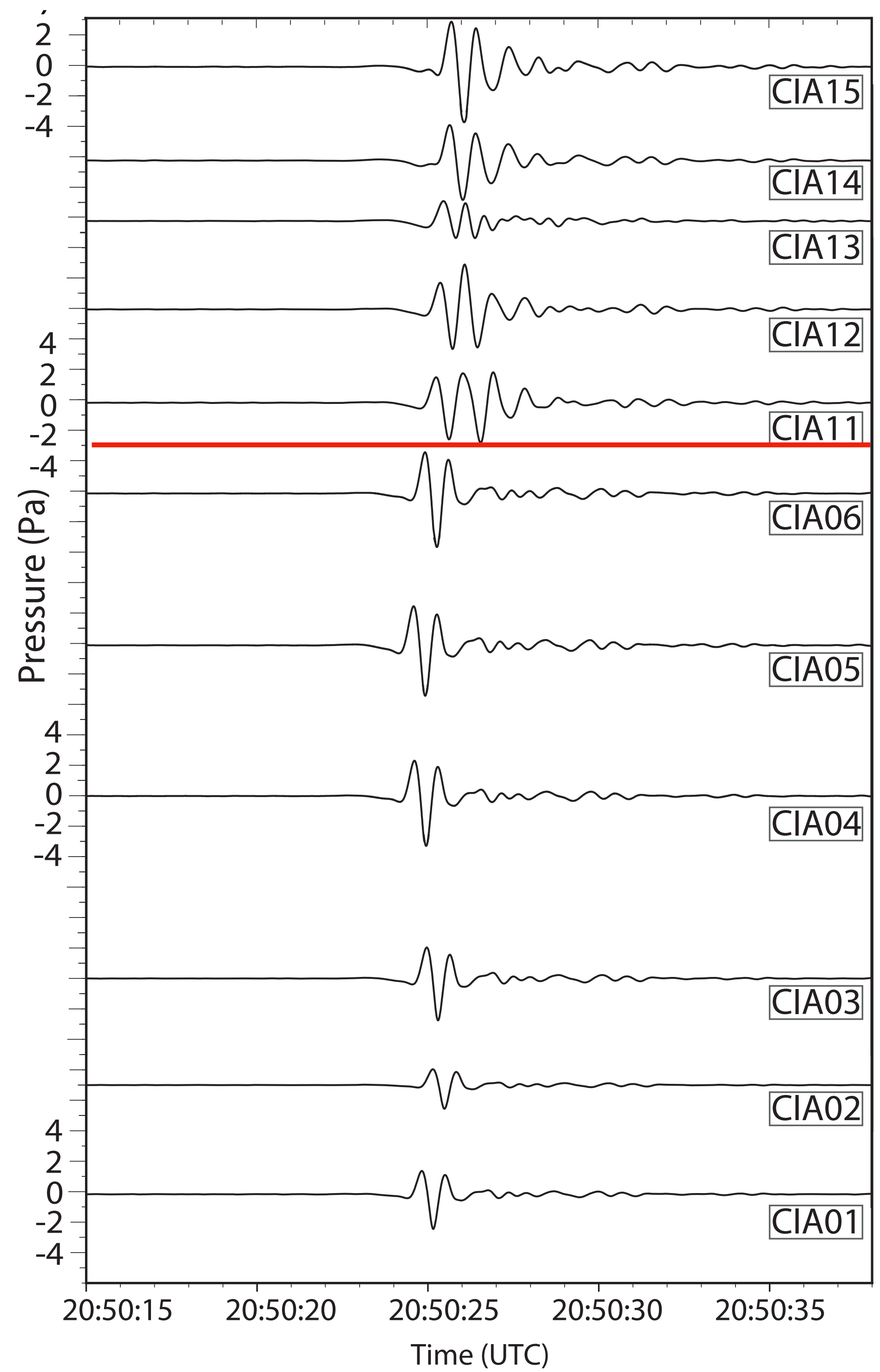
Influence Boundary layer on propagation

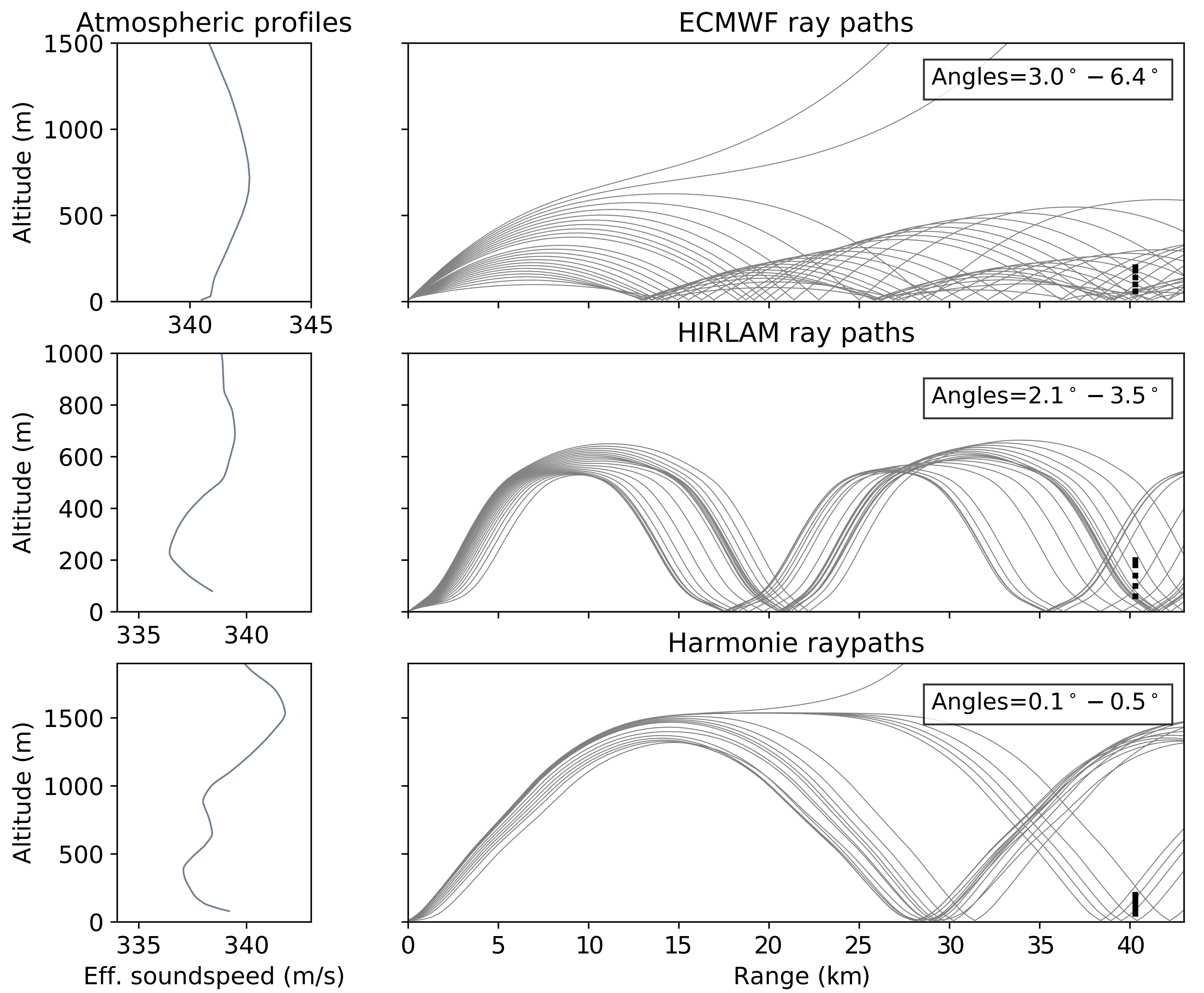
- Clear event of nearby explosion
- Amplitudes larger than noise levels



Atmospheric models

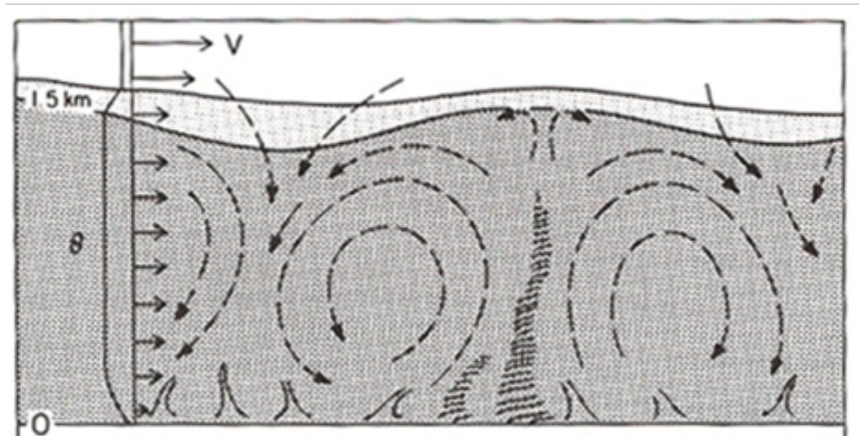
HIRLAM, HARMONIE and ECMWF

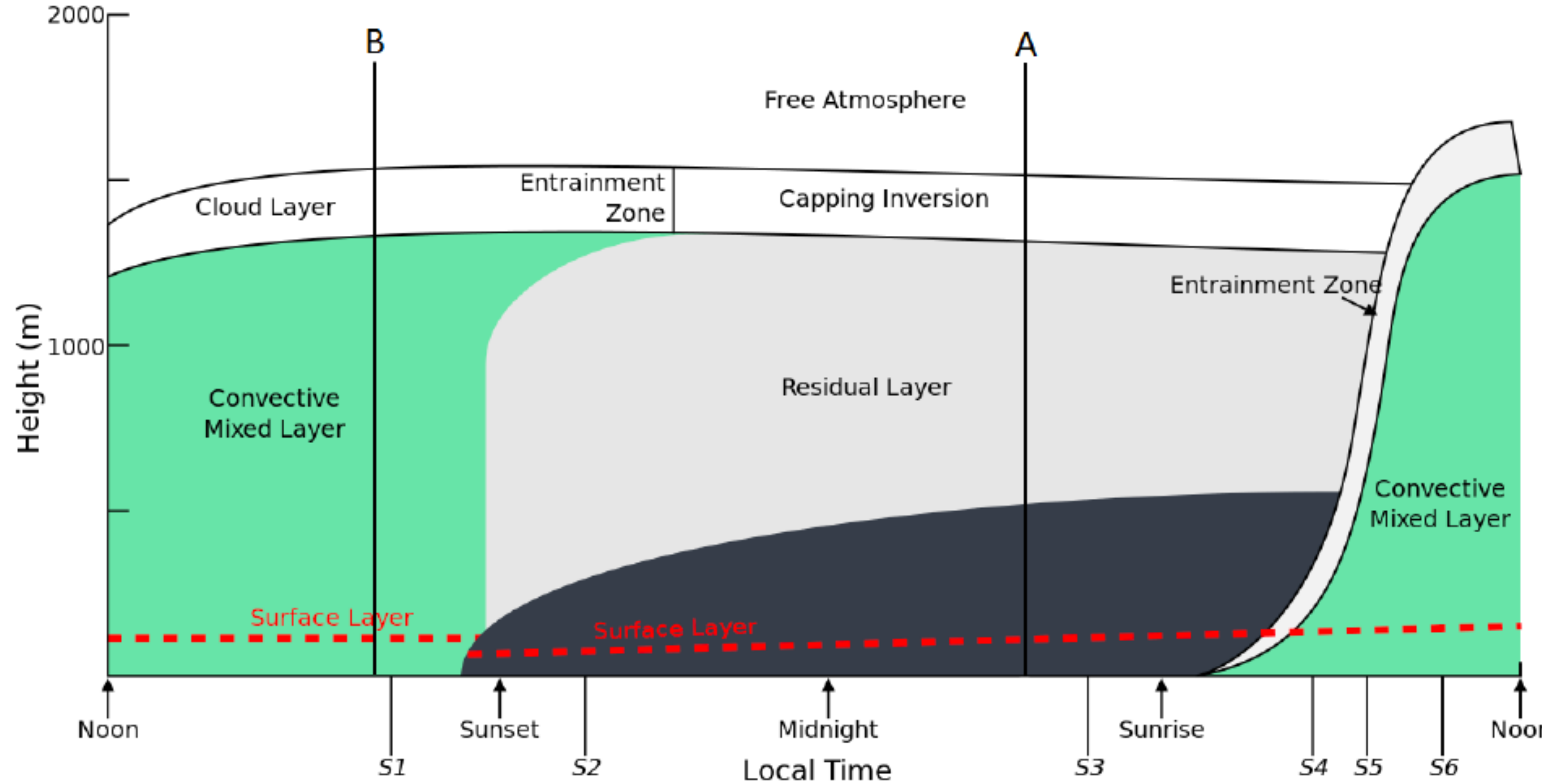
Influence of small scale variations on wavefront arrivals and ray paths

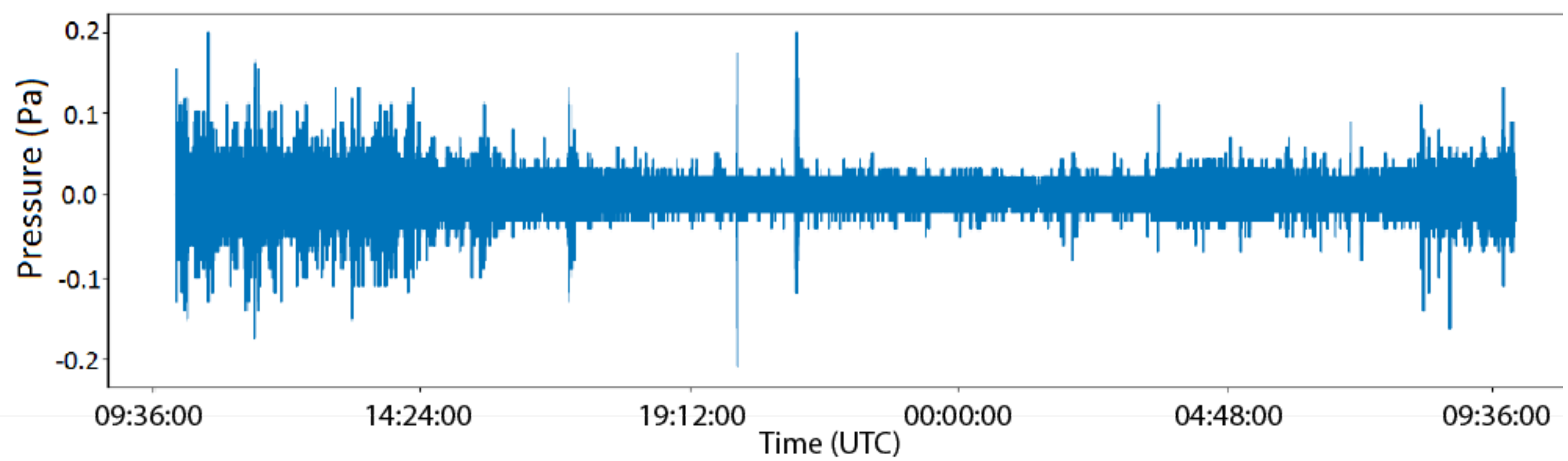


Influence of atmosphere

Local wind conditions determine the noise conditions near an infrasound microbarometer and therefore the detectability







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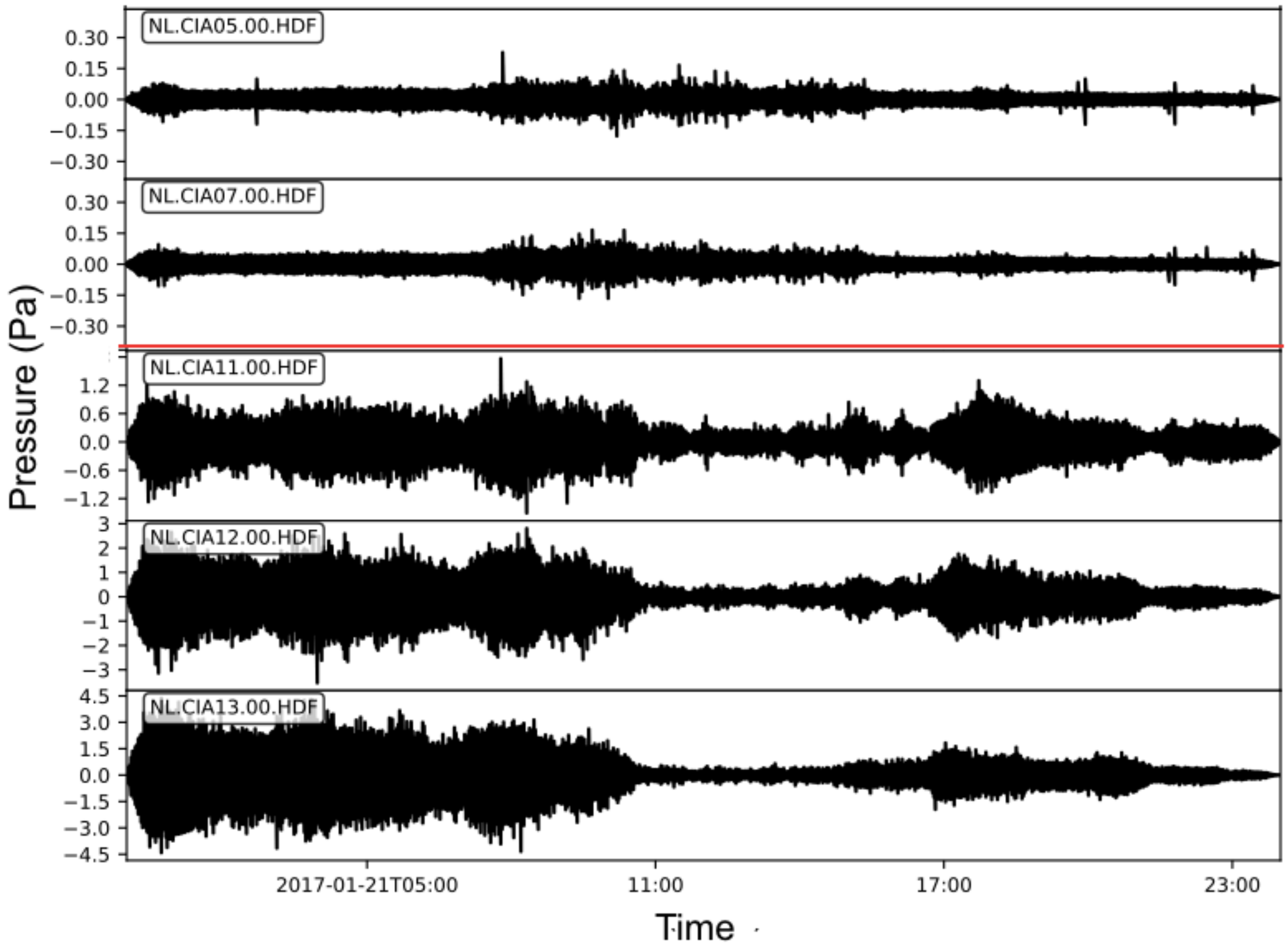
Tower and Ground Observations

Difference in noise periods and levels in ground and tower microbarometers



Wind noise

- Dominant source noise: **intrinsic pressure** fluctuations due to air turbulence interactions
  - Turbulence - turbulence interaction pressures
  - Turbulence - shear interaction pressures

- **Stagnation pressure**: interaction of bluff body with wind. Effect of measurement setup

Compare both with tower data

Understanding the data: stagnation and intrinsic pressure

- Estimating stagnation pressure (from Bernoulli's equation):

$$P_{\text{stag}} = \frac{1}{2}\rho u^2$$

$$P'_{\text{stag}} = P_{\text{stag}} - \overline{P_{\text{stag}}} = \rho \bar{u} u' + \frac{1}{2}\rho u'^2 - \frac{1}{2}\rho \overline{u'u'}$$

$$P'_{\text{stag}} \approx \rho \bar{u} u' \longrightarrow \boxed{\sigma_{\text{Pstag}} \approx \rho \bar{u} \sigma_u}$$

Assuming that velocity = 0 at stagnation point

- Estimating intrinsic pressure:

Beginning with Navier Stokes (George et al. 1984)

$$\frac{1}{\rho}\nabla^2 P_{\text{intr}} = -\frac{\partial u_i \partial u_j}{\partial x_i \partial x_j}$$

Complicated to solve, estimated by:

$$\boxed{\sigma_{\text{Pintr}} \approx \rho \sigma_u^2}$$

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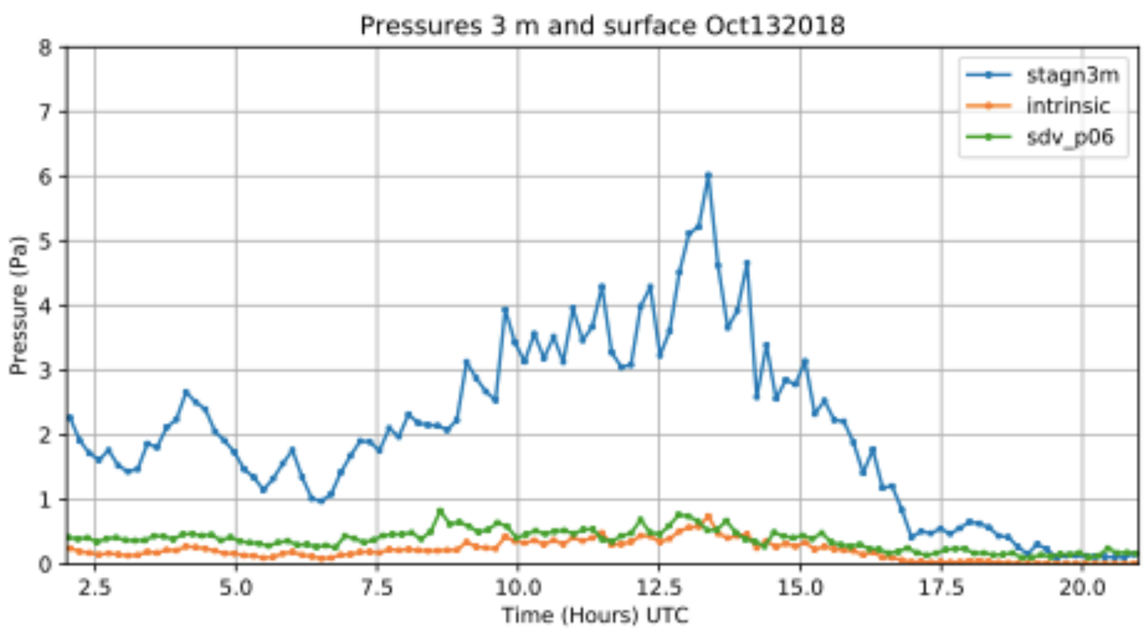
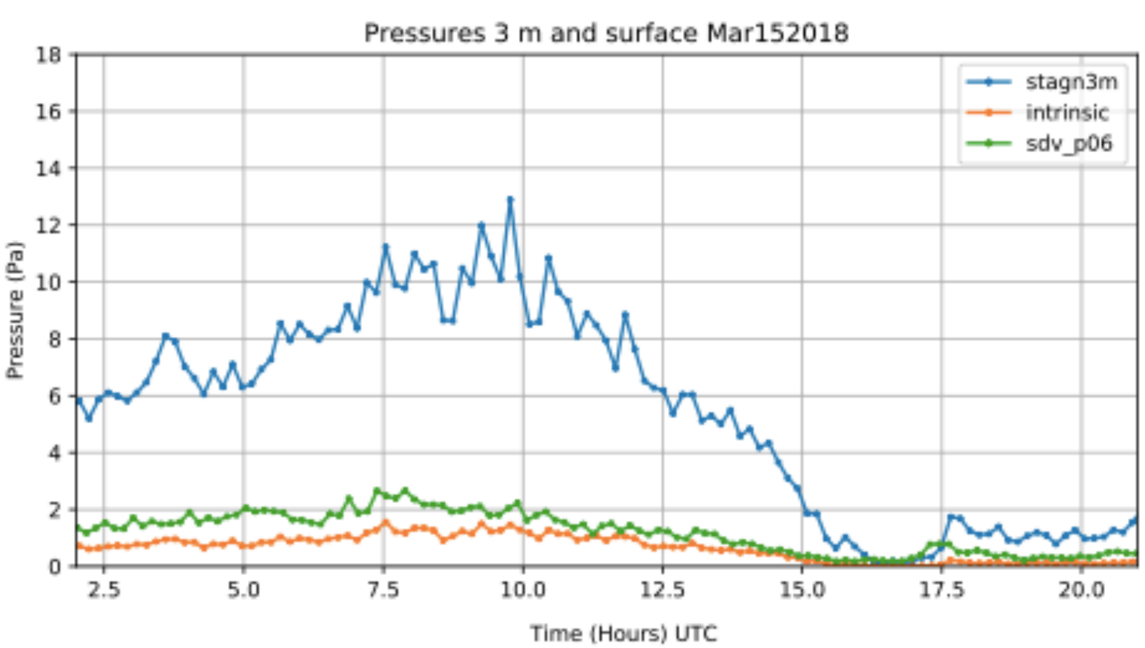
Stagnation, intrinsic, microbarometer pressure

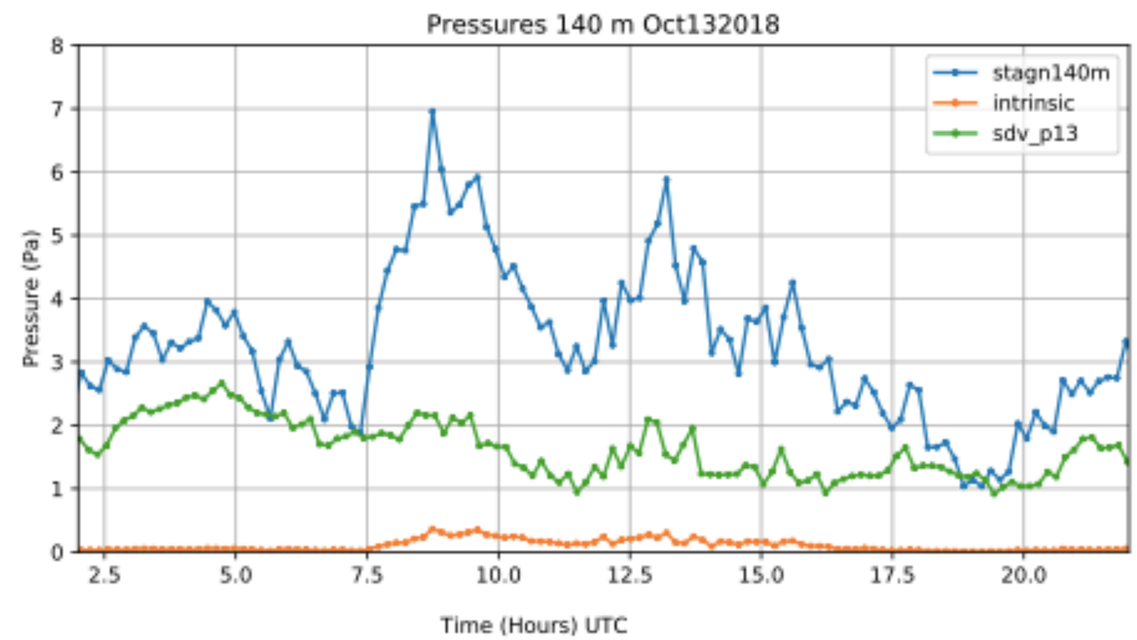
Approached stagnation and intrinsic pressure compared to the tower microbarometer data and tower data, using the high resolution sonic anemometers.

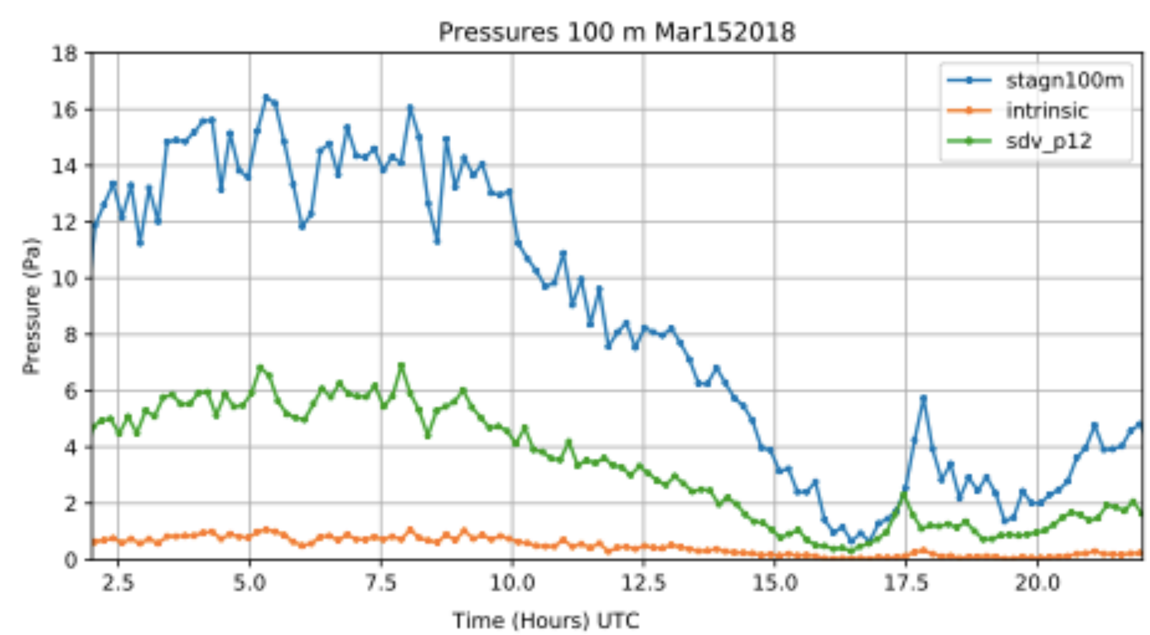
Ground





Tower





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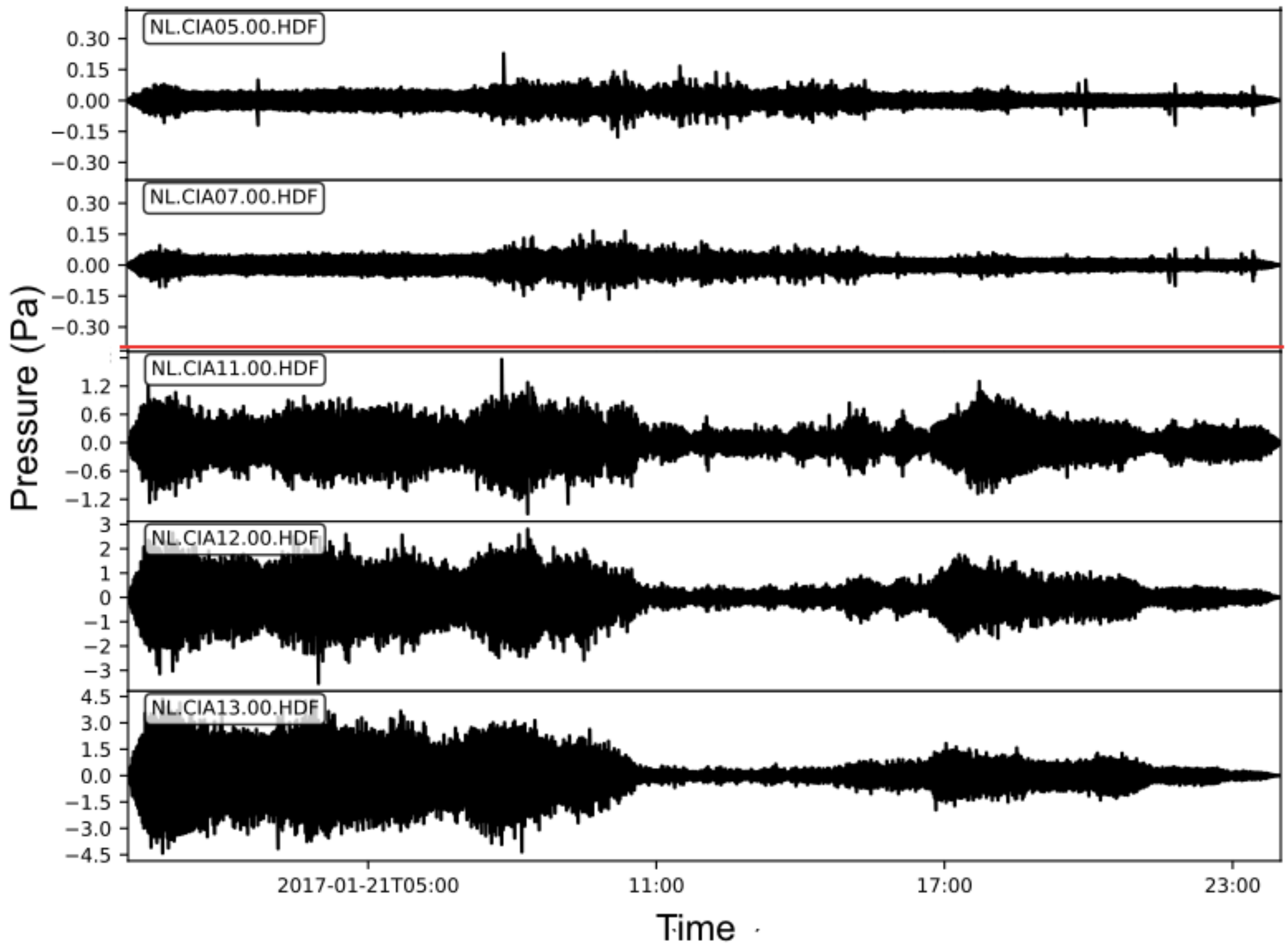
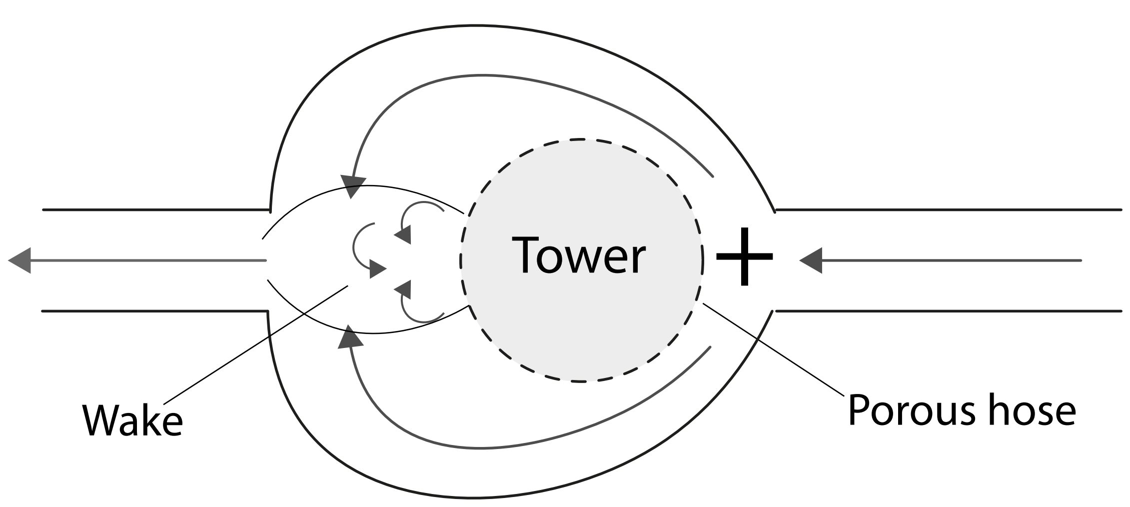


Work in progress

- Focussing on flow conditions and its influence on the suppression of stagnation pressure:
  - Using wavenumber spectra (with power law theories)
    - -7/3 power law for turbulence- turbulence interaction
    - -5/3 power law stagnation (from Kolmogorov's energy spectrum)

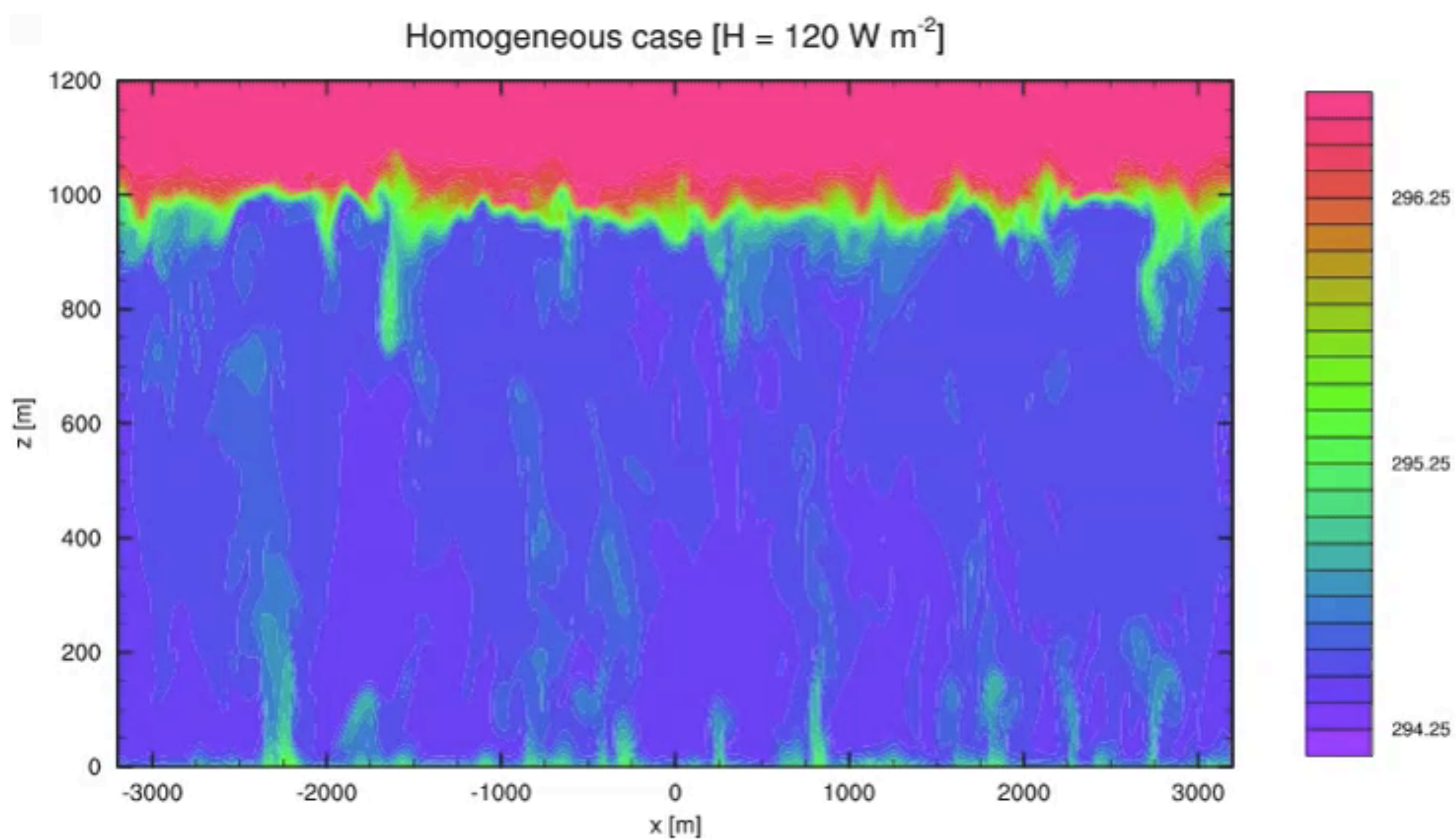
  - Understand flow around cylinder, flow separation and wake forming

- Apply corrections or improving stagnation pressure reduction systems.
- Comparing coherency between tower measurements



Conclusion points

- Understand noise in infrasound measurements, to improve future microbarometer array locations
- What processes cause the noise
  - Intrinsic pressure
  - Stagnation pressure
- Understanding influence of noise reduction system and uncertainties in the influence of the stagnation pressure (velocity $\neq 0$)




Thank you!
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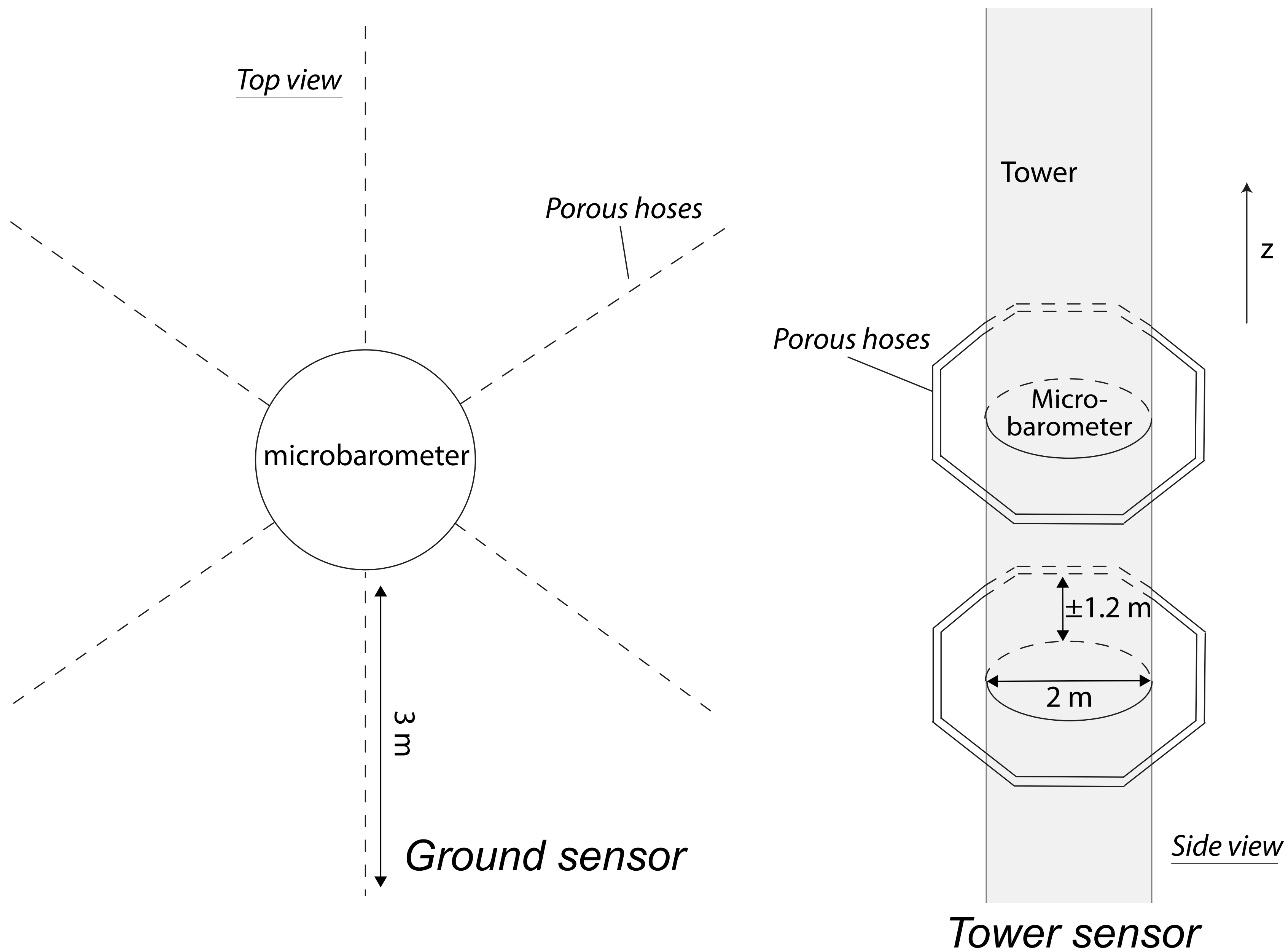
Suppressing wind noise

- Noise filtering: Porous hoses for sampling and averaging over a larger area

Ground: spider shape
Tower: surrounding tower

- Cancelling incoherent small scale wind fluctuations



Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO)

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Influence of atmosphere

- Infrasound propagation depends on wind and temperature conditions