Wind fluctuations affect the mean behaviour of naturally ventilated systems

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Climate change and Urban Heat Island

Urban Heat Island (UHI)

CANOPY-LAYER HEAT ISLAND

NOCTURNAL URBAN HEAT ISLAND
Building natural ventilation

Basic concepts
Building natural ventilation – opposing wind

Influence of an ‘opposing wind’
Building natural ventilation – opposing wind

Influence of an ‘opposing wind’
Building natural ventilation – opposing wind

Role of atmospheric turbulence?
Building natural ventilation – opposing wind

\[ -\frac{d\hat{h}}{df} = \begin{cases} \hat{h}^{5/3} - |V\hat{P}|^{1/2} & (a) \\ \hat{h}^{5/3} + |V\hat{P}|^{1/2} & (b) \\ 0 & (c) \end{cases} \]

and

\[ \frac{d}{df}[\hat{g}(1 - \hat{h})] = \begin{cases} 1 - |V\hat{P}|^{1/2}\hat{g} & (a) \\ 1 & (b) \\ 1 - |V\hat{P}|^{1/2}\hat{g} & (c) \end{cases} \]

where

\[ V = \left( \frac{A^*}{C^{3/2}H^2} \right)^2, \quad \hat{P} = \hat{B} - W, \]

where \( \hat{B} = [\hat{g}(1 - \hat{h})] \)

\[ W = \frac{\Delta p/\rho}{g_H H} \]
Building natural ventilation – opposing wind

\[ \Delta p \]
Random wind forcing

Fluctuation can then be modelled as

$$\mathrm{d}v'(t) = av'(t)\mathrm{d}t + b\mathrm{d}\Omega(t),$$

where $\Omega(t)$ is a standard Brownian motion, $a = -\tau_{wv}^{-1}$, and $b = c_{wv}^{1/2}$, where $c_{wv} = 2\sigma_{wv}^2/\tau_{wv}$.

Ornstein–Uhlenbeck stochastic process

exponentially autocorrelated as

$$\langle v'(t)v'(t + \tau) \rangle = \sigma_{wv} \exp[-\tau/\tau_{wv}]$$

$$W(t) = \chi v^2(t) = \frac{W_0}{v_0^2} v^2(t) = W_0 \left[ \frac{v_0 + v'(t)}{v_0} \right]^2 = W_0 \left[ 1 + \frac{v'(t)}{v_0} \right]^2$$

$$v'(t + \Delta t) = v'(t) \cdot \zeta + \sigma_{wv} \cdot \sqrt{1 - \zeta^2} \cdot n$$

$$\zeta = \exp \left[-\Delta t/\tau_{wv}\right] \quad \quad C_{V,wv} = \sigma_{wv}/v_0$$
A stochastic perturbation (with zero mean) added to a constant wind does not just induce fluctuations with zero mean around the system steady-configuration of equilibrium attained with constant wind.
Role of atmospheric turbulence

Effect of the noise parameters on the average interface elevation \( (a) \) and average reduced gravity \( (b) \)

![Graphs showing the effect of noise parameters on interface elevation and reduced gravity](image)

The dimensionless correlation time \( \hat{\tau}_{wv} \) was varied from 0.05 (highest curves for a given \( W \)) to 0.15 (lower curve).
Role of atmospheric turbulence

\[ W(t) \]

\[ W_0 + \Delta W \]

\[ W_0 - \Delta W \]

\( t \)

\( g_1' \)

\( Q_T \to \)

\( Q_P \)

\( h_3 \)

\( T11 \)

\( g_2' \)

\( Q_T \to \)

\( Q_P \)

A

\( h_2 \)

\( T12 \)

\( g_3' \)

\( Q_T \to \)

\( Q_P \)

B

\( h_3 \)

\( T13 \)

\( g_4' \)

\( Q_T \to \)

\( Q_P \)

B

\( h_4 \)

\( T14 \)

\( g_5' \)

\( Q_T \to \)

\( Q_P \)

C

\( h_5 \)

\( T15 \)

\( g_6 \)

\( Q_T \to \)

\( Q_P \)

D

\( h_6 \)

\( T16 \)
Experimental campaign

Obstacle reproduces wind fluctuations

Release of carbon dioxide
Experimental campaign

Flow Visualisations

Steady wind forcing

Random wind forcing
Comparison between experimental data and model prediction
Results

Comparison between experimental data and model prediction
Results

Comparison between experimental data and model prediction
Conclusions

The role of an atmospheric turbulence induces:

1. A dilution of buoyancy in the buoyant layer
2. A fluctuation of the height of the buoyant layer
3. A reduction of the time averaged height of the buoyant layer
4. A transition to the full-mixed regime for lower values of the ‘wind parameter’

Thank you for your attention
Death toll exceeded 70,000 in Europe during the summer of 2003

Jean-Marie Robine, Siu Lan K. Cheung, Sophie Le Roy, Herman Van Oyen, Clare Griffiths, Jean-Pierre Michel, François Richard Herrmann

Daily numbers of deaths at a regional level were collected in 16 European countries. Summer mortality was analyzed for the reference period 1998-2002 and for 2003. More than 70,000 additional deaths occurred in Europe during the summer 2003. **Major distortions occurred in the age distribution of the deaths, but no harvesting effect was observed in the months following August 2003.** Global warming constitutes a new health threat in an aged Europe that may be difficult to detect at the country level, depending on its size. Centralizing the count of daily deaths on an operational geographical scale constitutes a priority for Public Health in Europe.