Effects of Sea Breeze on City Ventilation - Important for Air Ventilation Assessments?

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Why did we do it

- As urban population increases, preserving an acceptable city climate becomes a major challenge of future city planning
- Air Ventilation Assessments (AVAs) help city planners to predict city ventilation of planned construction sites
- To sufficiently predict ventilation, an AVA must cover the real atmospheric situation
- Current AVA focus only on neutral conditions
  → Is this sufficient for summer weak-wind conditions in a coastal city area?

How did we do it

- LES simulation of Kowloon peninsula (Hong Kong), using the model PALM
- Summer weak-wind condition:
  - easterly background wind: 1.5 ms⁻¹, fixed surface heat flux: 200 Wm⁻²
- Two cases:
  - homogeneous heating throughout domain
  - sea-breeze case where only land is heated
- Divide city into 3 regions (according to [2]):
  - C1: SW ventilated; C2: weakly ventilated; C3: SE ventilated
- Passive scalar released at surface within city area

How is the ventilation?

- Sea breeze penetrates city area along the entire coastline, forming a convergence zone above the city
- Higher $V_r$ at west coast due to lower building density and flat terrain
- Comparison shows higher $V_r$ in sea-breeze case especially in western part of Kowloon

Is the pollution dispersion influenced by sea-breeze?

- Scalar concentration differs significantly between cases
  - Strong west-east gradient in sea-breeze case, north-south homog. in homog. heating case
- Different wind fields yield large differences in $s^*$ between cases
  - Depending on case, high $s^*$ values are observed in different city areas

Looking at different city regions

- C1, C2, C3 correspond to different city regions according to [2]
  - Mean wind direction (dir, Tab.1) agrees with classification made by [2] for sea-breeze case but not for homog. heating case
- Although C1 has highest ventilation, pollution is also highest
  → Between Kowloon and Hong Kong Island, complex wind circulation transports pollution over sea where it re-enters the city area
- Vanishingly low correlation between $V_r$ and mean building height $H_{avg}$ confirm that $H_{avg}$ plays a minor role for city ventilation (Fig.4, see also [1])

Let’s summarize

- Ventilation changes significantly between sea-breeze case and homogeneously heated case in strength and direction
- More complex wind circulation lead to differences in pollution concentration (W-E gradient instead of N-S)
- Main wind direction from measurements can only be reproduced if sea-breeze is considered
  → It is essential to cover sea-breeze effects if a sufficient analysis of the city ventilation is focused during summer weak-wind conditions.

What’s next

- Further detailed analysis of wind system between Kowloon and Hong Kong Island should reveal more details of sea-breeze effects on ventilation
- Compare results with real-world measurements in Hong Kong
- Using PALM’s new nesting methods, a larger area can be simulated to study effects of large-scale wind systems
  (see also poster 1D-51)

References & Acknowledgments


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