FIELD EXPERIMENTS OF FLOW AND DISPERSION WITHIN STREET CANYONS USING OUTDOOR URBAN SCALE MODEL

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Background1

In urban (built-up) areas;

- Many small sources of pollutants
  - ✓ Motor vehicles
  - ✓ Low chimneys
  - ✓ Distributed power generators
- Accidental / deliberate releases
  - ✓ Hazardous materials
  - ✓ Toxic substances

→Flow and pollutant transport in near buildings (street canyons, obstacle arrays)

Background2

Flow and dispersion inside street canyons;

- Field measurements
- Laboratory scale physical modelling (wind tunnel, water channel, towing tank)
- Computational Fluid Dynamics (k-ε , LES)
  - ✓ Aspect ratio (building height/building width)
  - ✓ Step-up and step-down notch
  - ✓ Roof shape (flat vs. slanted)
  - ✓ Wind speed, direction
  - ✓ Wall (Floor) heating

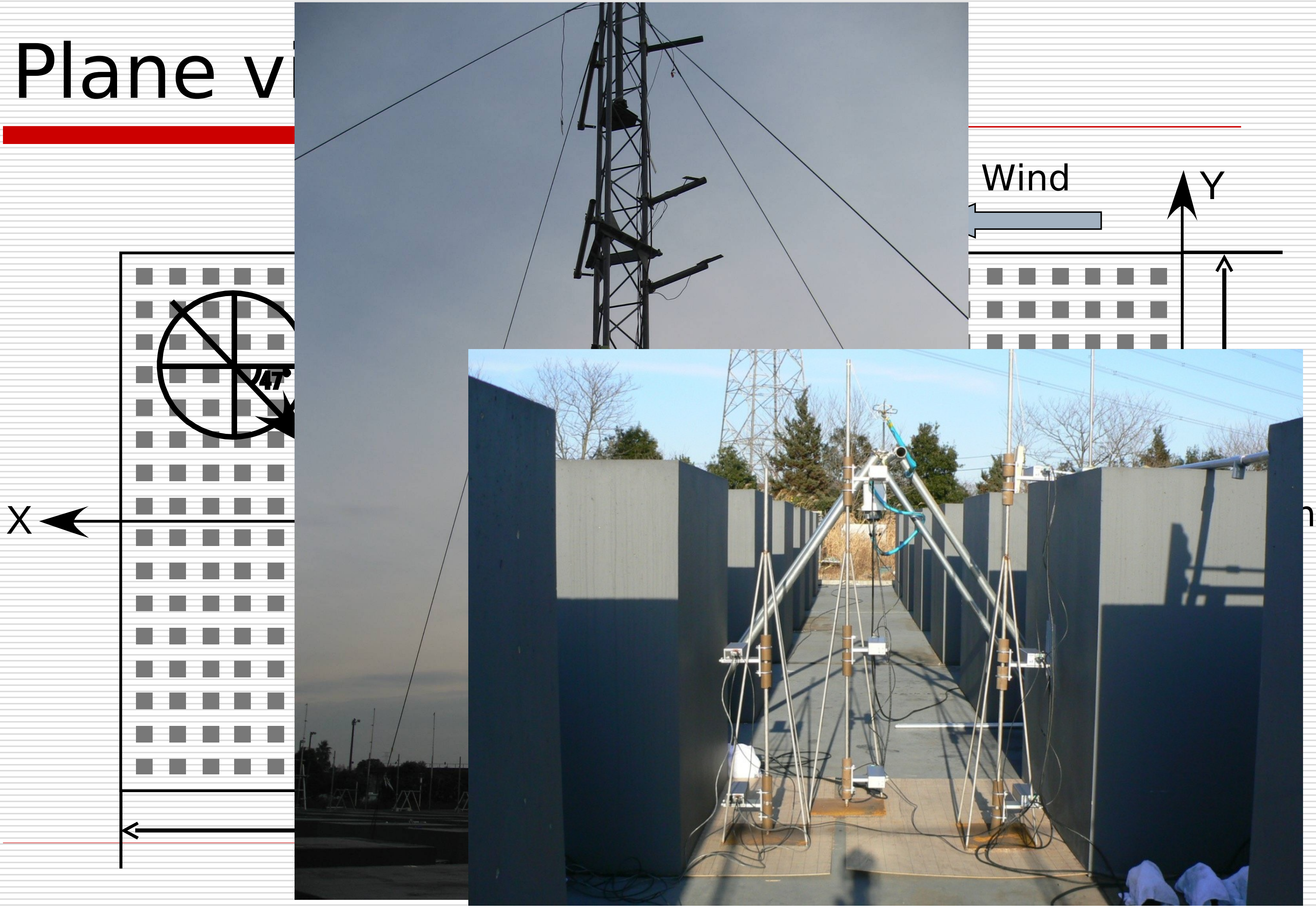
➡ Effects of atmospheric turbulence???

COSMO

COSMO=Comprehensive Outdoor Scale MOdel
experimental facility for urban climate

- Saitama Prefecture, JAPAN
- Size of the test site=50m×100m
- Block height & width=1.5m
- Number of blocks=512
- Street width=1.5m
- Area density=25%
- 1/5 the scale of typical residential buildings

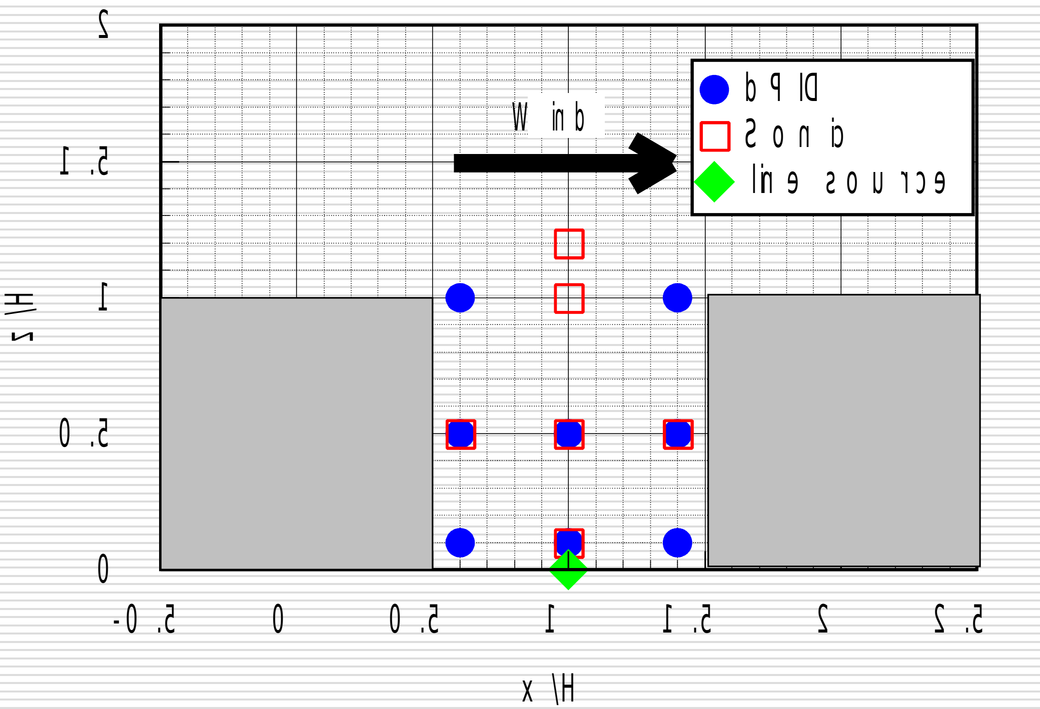
Plane vi



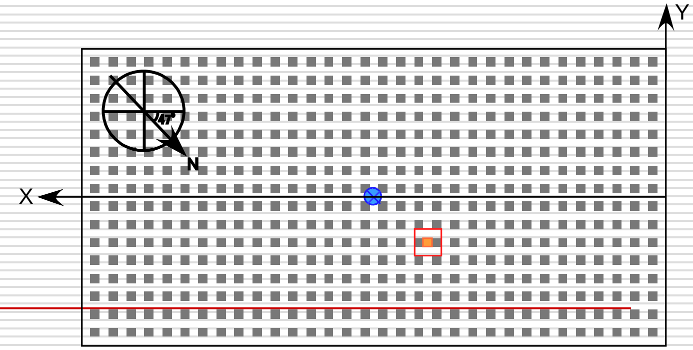
Measuring instruments

- Concentraion
  - digitalPID (Aurora Scientific Inc.)x8
  - Tracer gas ： Propylane(C_3H_6)
  - Line source ： L=1.5m
  - Flow volume ： 1～4L/min.
  - Sampling time ： 30min./RUN
  - Sampling frequency ： 50Hz
- Velocity
  - Ultra sonic anemometer (Kaijyo DA-600 & TR90-AH)×6
  - Sampling frequency ： 50Hz

Layout of instruments



Flow characteristics measured at z=2H



RUN	Date	U(m/s)	ϕ(deg)	σ_u(m/s)	σ_v(m/s)	σ_w(m/s)	u*(m/s)	z'/L
1	Jan. 31	6.0	-8	2.13	1.87	1.07	0.84	-0.008
2	Jan. 31	5.2	-10	2.01	1.76	0.91	0.71	-0.012
3	Jan. 31	4.5	-18	1.82	1.83	0.89	0.66	-0.014
4	Jan. 31	4.3	-18	1.95	1.62	0.85	0.66	-0.015
5	Jan. 31	4.6	-18	1.85	1.86	0.93	0.66	-0.015
6	Jan. 31	4.9	-13	2.01	1.75	0.94	0.74	-0.009
7	Jan. 31	4.2	-11	1.76	1.35	0.79	0.64	-0.009
8	Jan. 31	3.3	-21	1.54	1.13	0.67	0.53	-0.010
9	Jan. 31	3.3	-15	1.41	1.28	0.70	0.52	-0.011
10	Feb. 01	5.3	9	1.90	1.57	0.88	0.72	-0.011
11	Feb. 01	4.9	-1	1.81	1.79	0.88	0.70	-0.013

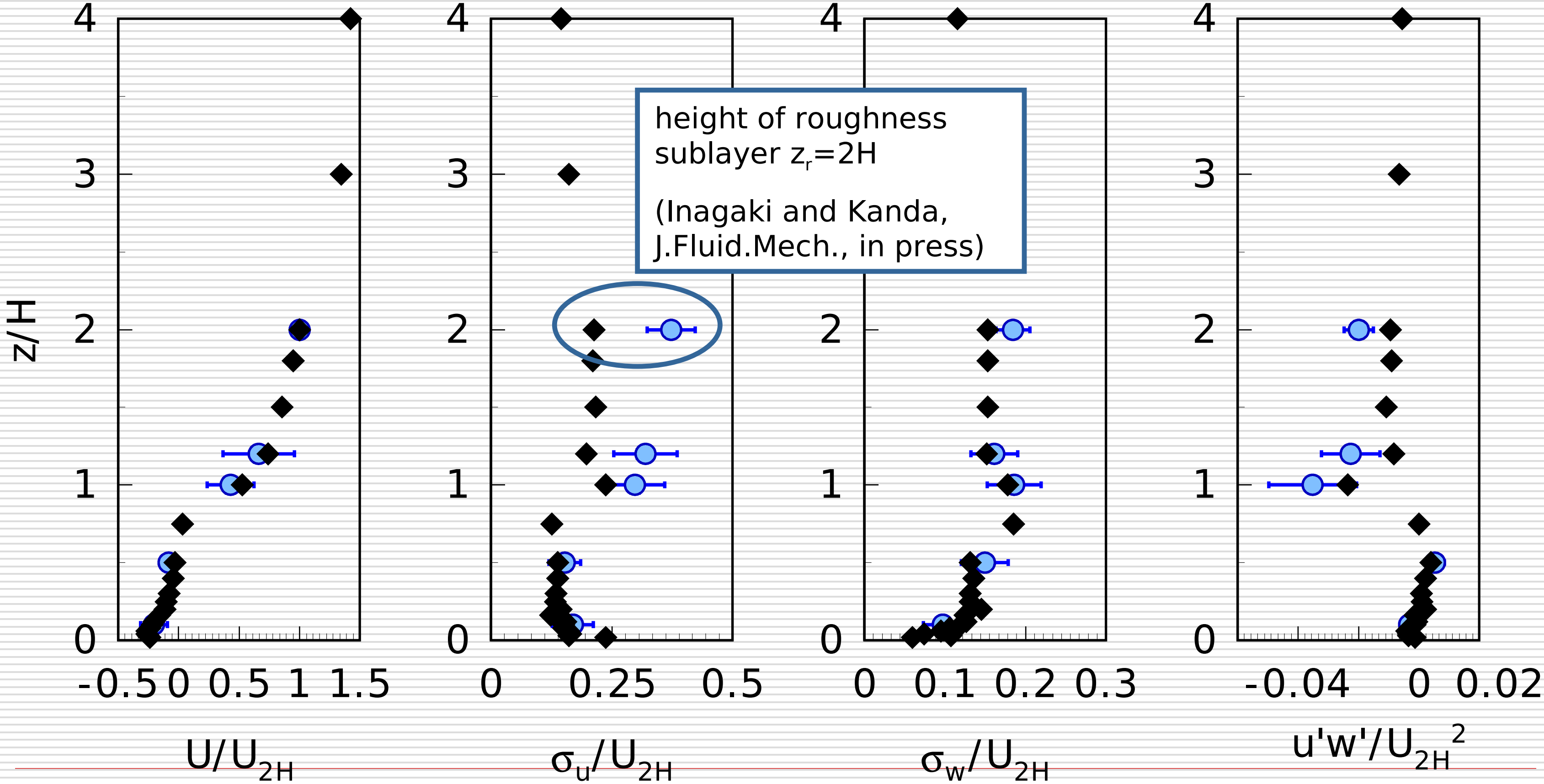
- Averaging time=3min. （=10cases x 11RUN）
- Wind directions=±10deg. -> 57cases

z'=z-d

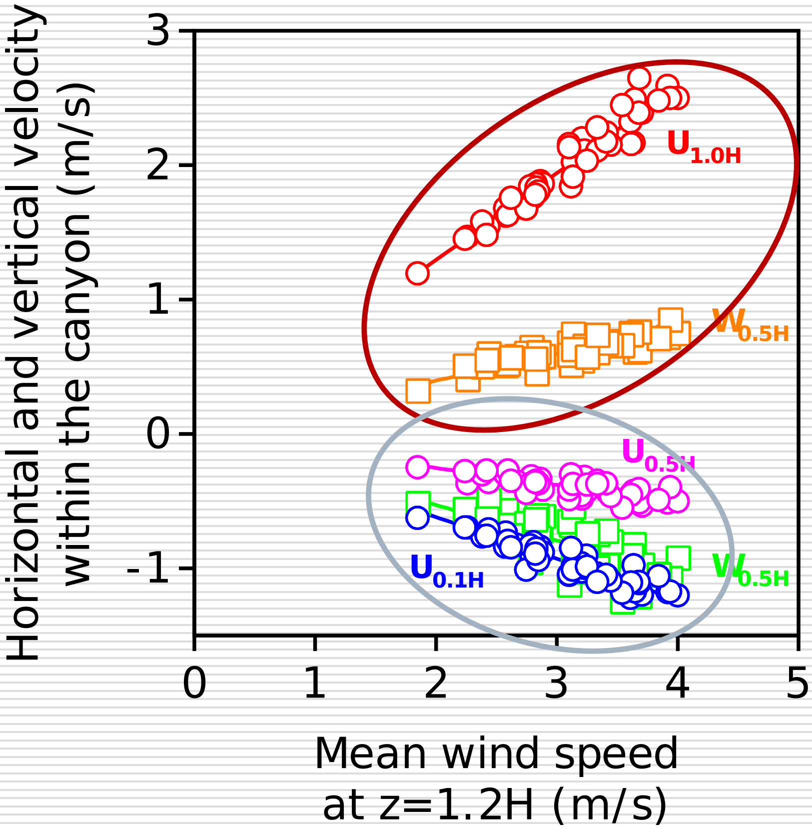
d: zero-plane displacement

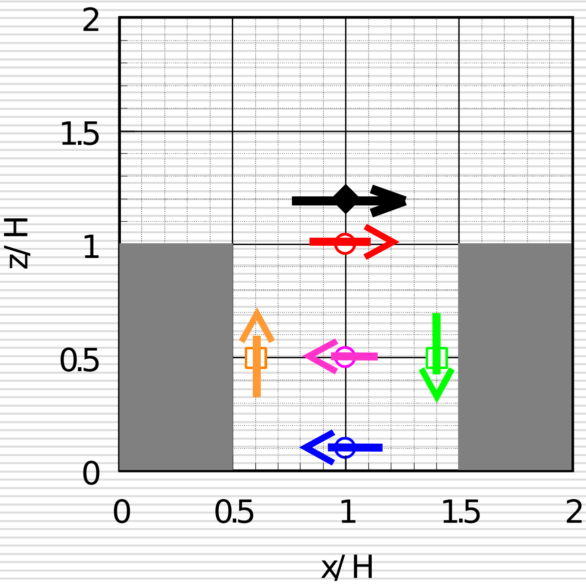
L: Monin-Obukhov length

Vertical profiles of mean velocity and turbulence statistics

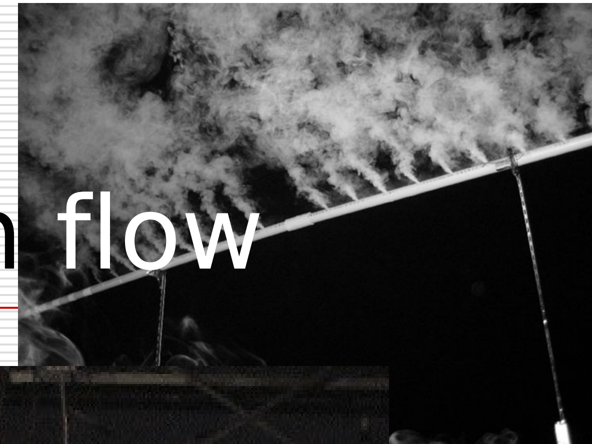


Horizontal and vertical velocity within the canyon

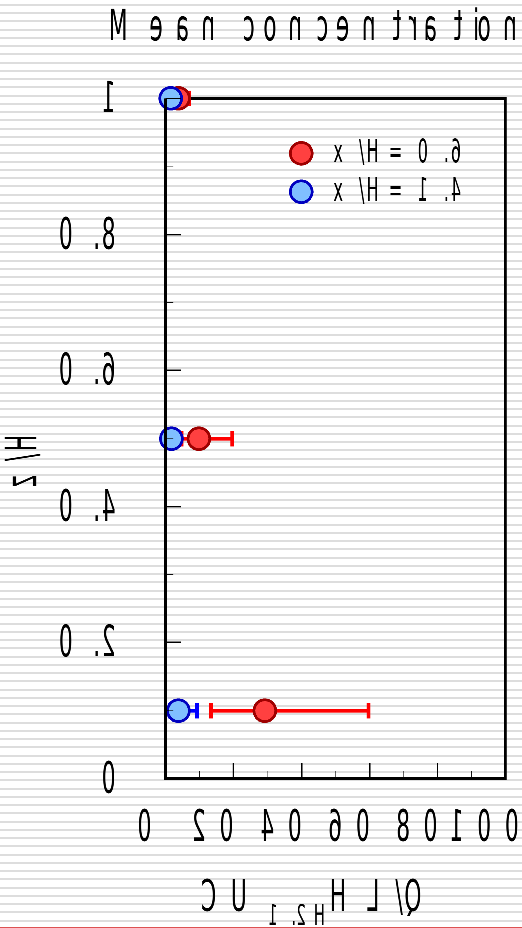


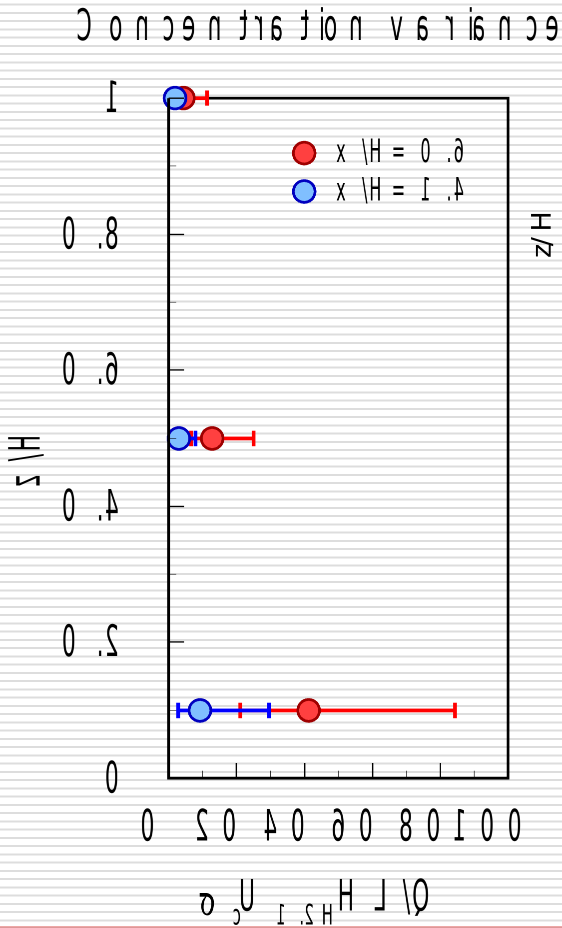


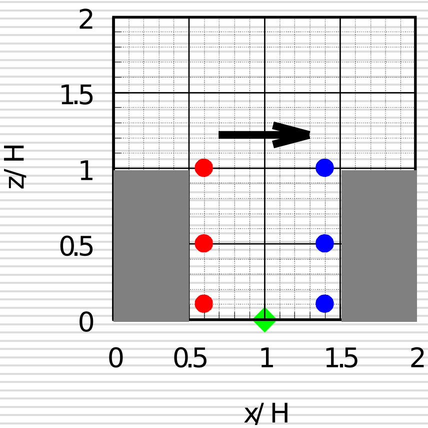
Visualization of canyon flow



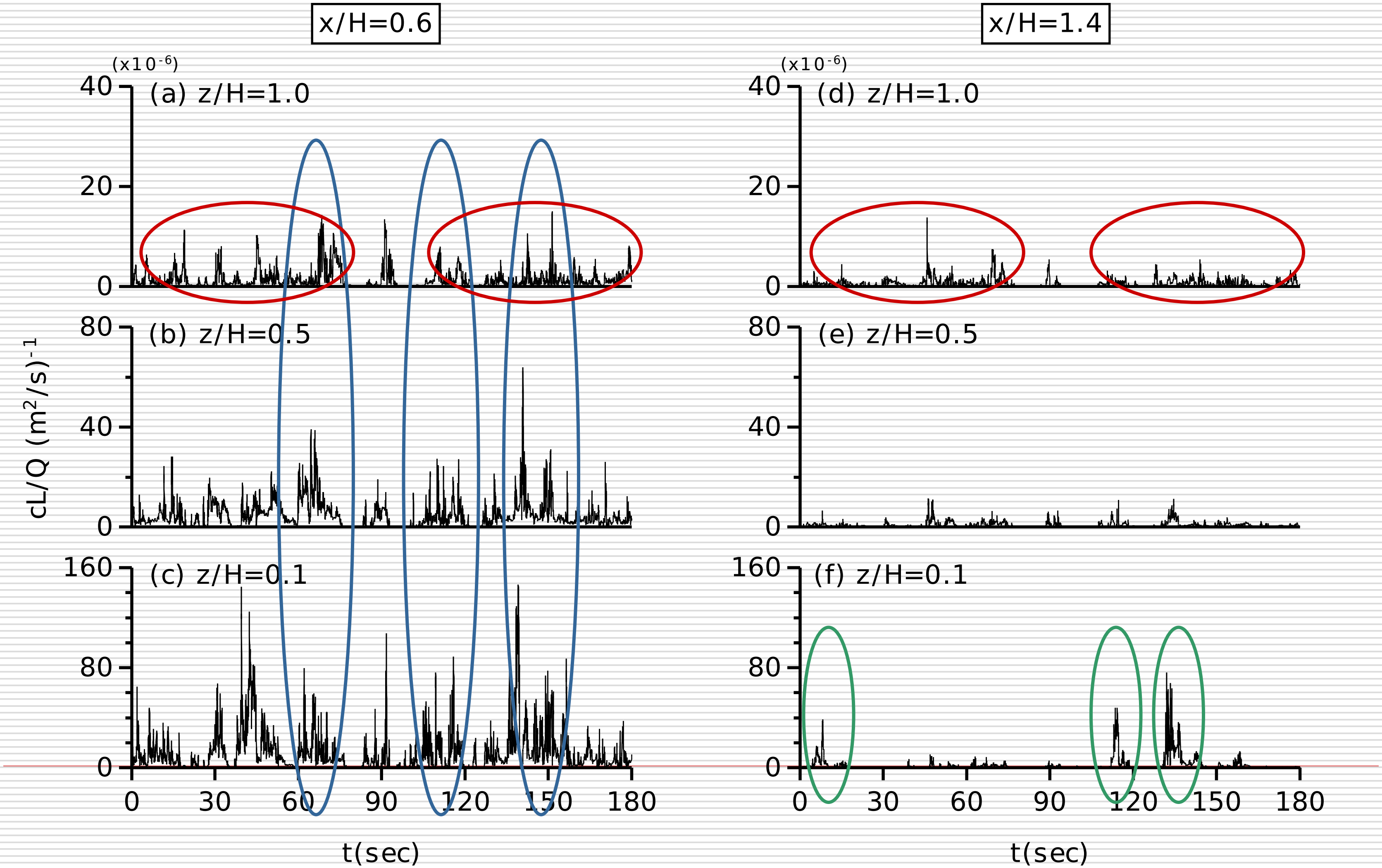
Vertical profile of tracer gas concentration



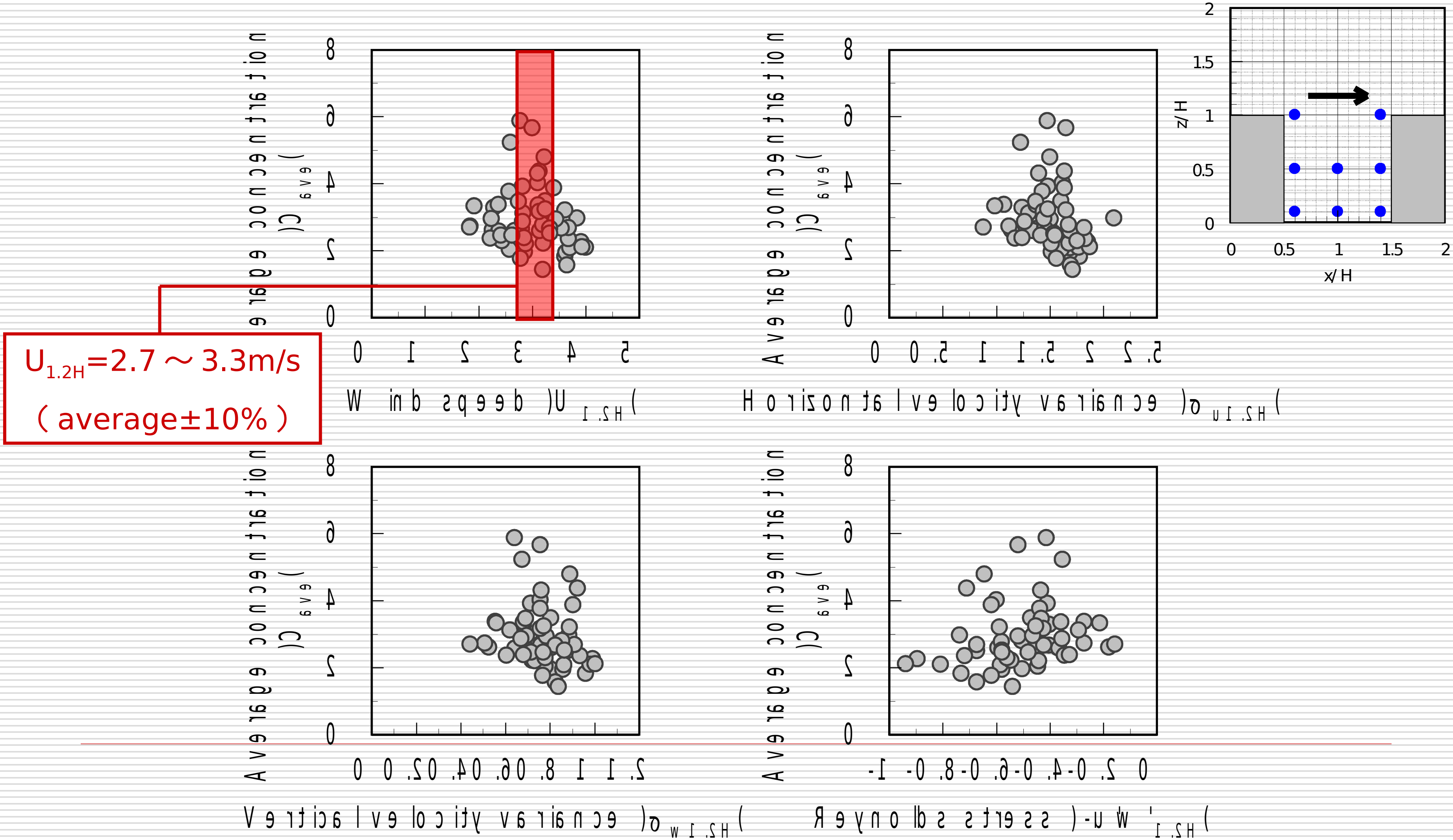




Time series of concentration measured within the canyon

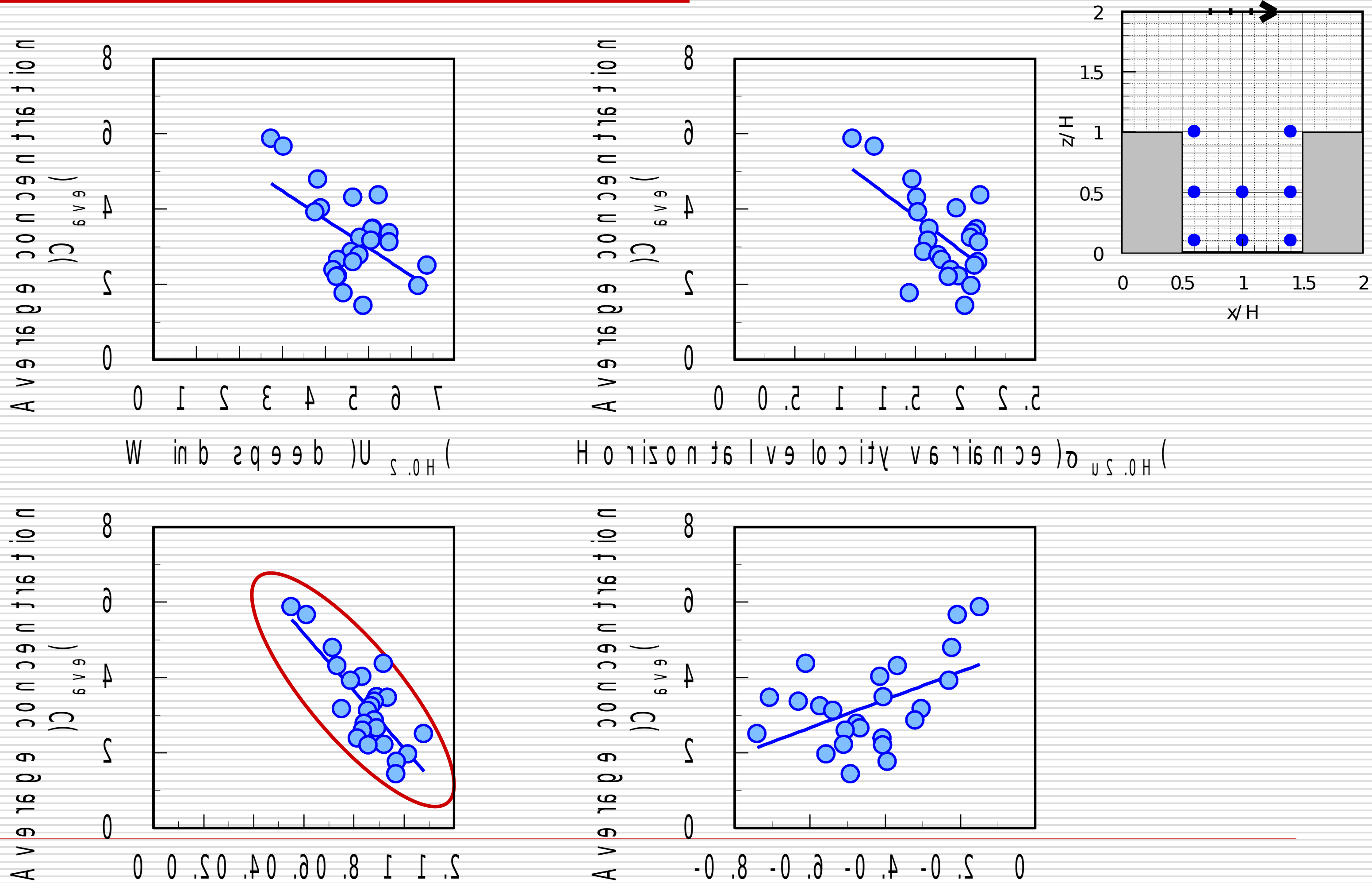


Velocity statistics measured at z=1.2H and average concentration

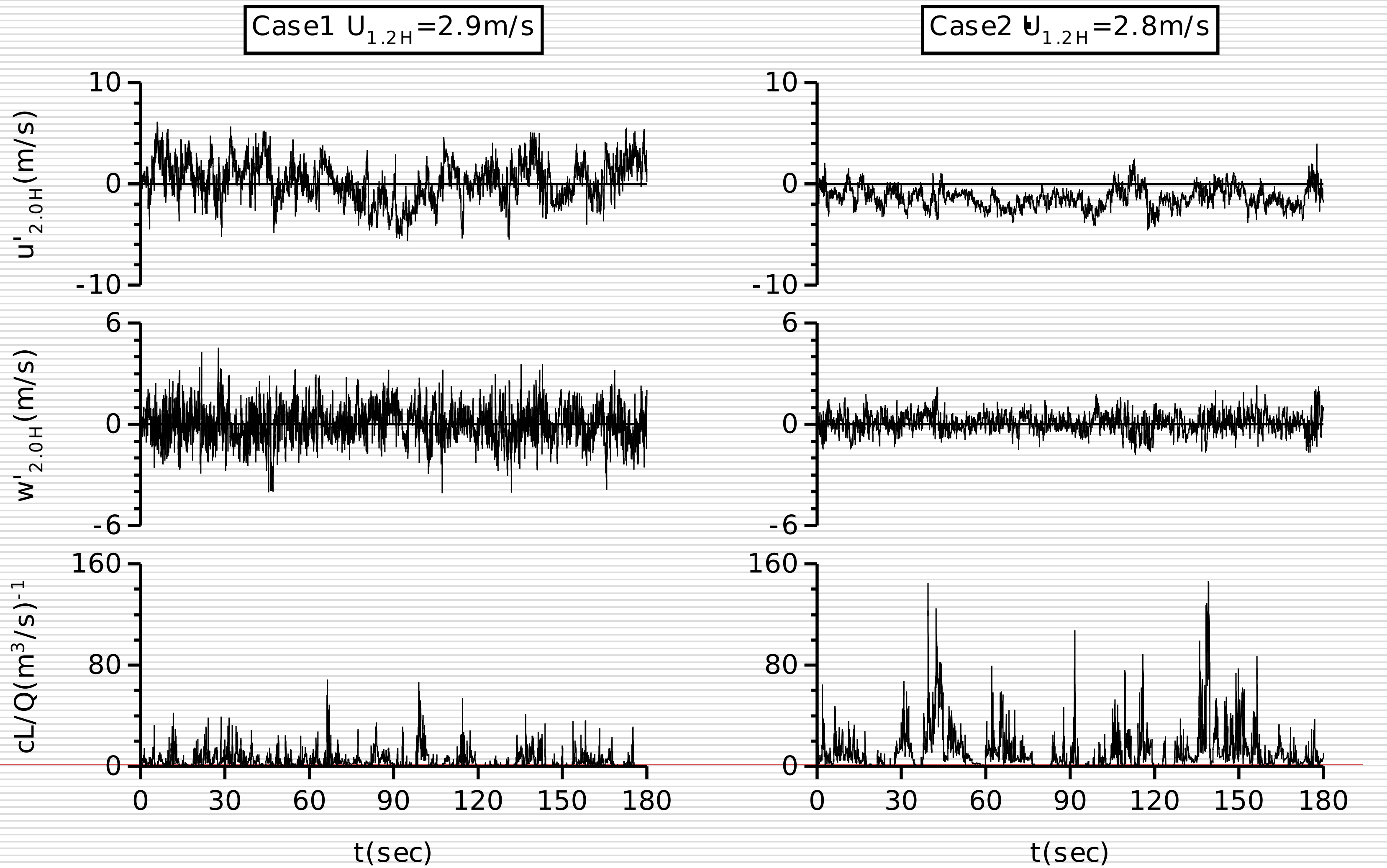


※$U_{1.2H}$=2.7～3.3m/s

Velocity statistics measured at z=2H and average concentration



Time series of fluctuating u’,w’ at z=2H and concentration near ground



Estimation of concentration

$$\frac{CL}{Q} = \frac{\sqrt{\pi}}{U_0 W}\left(\sqrt{\frac{\sigma_w^{ext}}{U_0}\,\frac{l^{ext}}{W}}\right)^{-1}$$

Caton, F., Britter, R.E. and Dalziel, S.,

Atmospheric Environment (2003)

C: Concentration

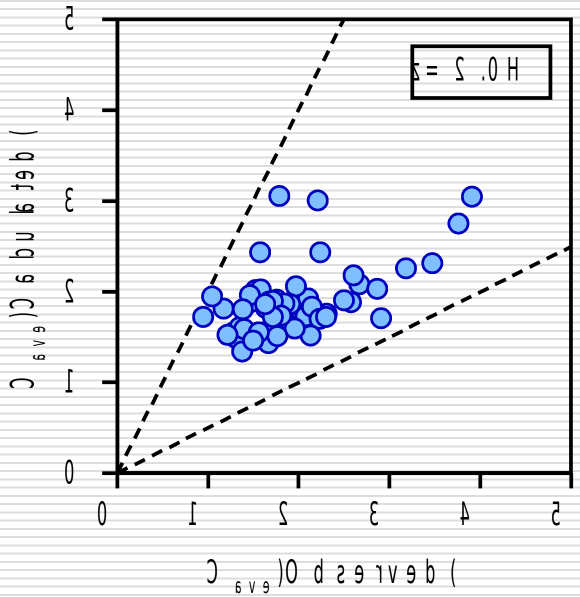
Q/L: Line source input rate

U_0: External velocity

W: Canyon width

σ_w^{ext}/U_0: Turbulence intensity

l^{ext}: Turbulence length scale



Conclusions

- A stable vortex-type flow was observed in the street canyon of the outdoor urban scale model, and the strength of the vortex was proportional to the above canyon wind speed.
- The tracer gas from the line source near the ground was carried to the leeward side of the upstream building by the vortex circulation, and the concentrations near the leeward side of the upstream building was higher than that measured at the windward side of the downstream building.
- Diffusion to the leeward side of the canyon by an unsteady turbulent flow and re-entry of the gas at the top of the canyon were verified by measuring the concentrations at several points within the canyon simultaneously.
- Average concentrations inside the canyon decreased with the mean wind speed and the velocity variances. Concentrations could be estimated by considering the external turbulence in addition to the wind velocity.