PO-28 - Modelli per la dispersione delle fluttuazioni di concentrazione

Enrico Ferrero[1,2]

[1] Università del Piemonte Orientale, Vercelli, Italy
[2] ISAC-CNR, Torino, Italy

Introduction

We follow the approach of Manor (2014) that proposed a single-particle Lagrangian stochastic model, that analyses the dispersion phenomena following a large number of particles from their source along their Lagrangian trajectory, with every particle motion being independent from the others. Despite being a Lagrangian model, concentrations are evaluated on fixed grid-points in a computational domain, like Eulerian models.

The Lagrangian model

To simplify the model equations we consider the turbulence to be effective only along the crosswind (y) and vertical (z) directions. Also along y it is considered homogeneous, while along z it is non-homogeneous. The resulting equations for the three velocity fluctuation components (u, v, w) are as follows:

$$du = \overline{U}dt$$

$$dv = -\frac{v}{T_{L_v}}dt + \sqrt{c_0\epsilon}dW_v(t)$$

$$dw = -\frac{w}{T_{L_w}}dt + \frac{1}{2}\left(1 + \frac{w^2}{\sigma_w^2}\right)\frac{\partial \sigma_w^2}{\partial z}dt + \sqrt{C_0\epsilon}dW_w(t)$$

where $\overline{U}$ is the mean wind speed, σ_u, σ_v and σ_w are the wind velocity component standard deviations, ϵ is mean dissipation rate of the turbulent kinetic energy, C_0 is the Kolmogorov constant and $\mathbf{W}(t)$ the Wiener process that embodies the stochastic nature of the phenomenon.

The Experiment

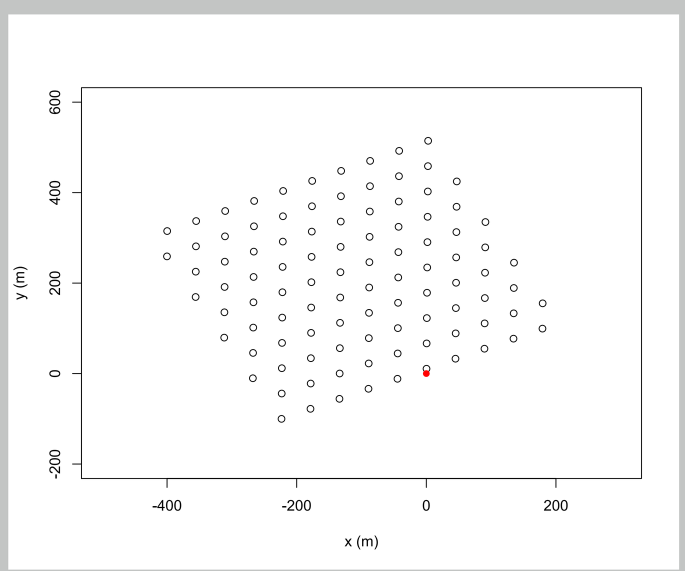

Figure: **Observations were taken by a set of 100 digital PID (Photo Ionization Detector) samplers, arranged in a rectangular staggered grid/array of area 475m × 450m in 10 rows and 10 columns**

In September 2007, experimental release trials called "FUsing Sensor Information from Observing Networks (FUSION) Field Trial -2007" were performed at Dugway Proving Ground in Utah (USA). This experiments were conducted by studying both instantaneous and continuous emissions with different number of sources. This poster treats three trials of continuous emission from single source: Trial14, Trial15, Trial45 and Trial46. The source height is 2 m and its diameter is 3 mm. On the basis of the Obukhov length the atmospheric conditions are unstable for Trial45 and neutral for trials 14 and 46. Model evaluation and analysis are performed over the entire duration of each tracer experiment lasting ten minutes, in which the atmospheric stability can be considered constant. We use ten minute averages and standard deviations.

Trial 14

Table: Statistical analysis for the mean concentration and the concentration standard deviation in the neutral case Trial14. m indicates measured and c calculated.

Trial14

	mean m (g/m^3)	mean c (g/m^3)	FB	NMSE	R	FAC2 (%)	FAC5 (%)
MEAN	**0.0012**	**0.0014**	**−0.21**	**6.49**	**0.40**	**17**	**33**
STD	**0.0023**	**0.0058**	**−0.86**	**7.99**	**0.33**	**6**	**17**

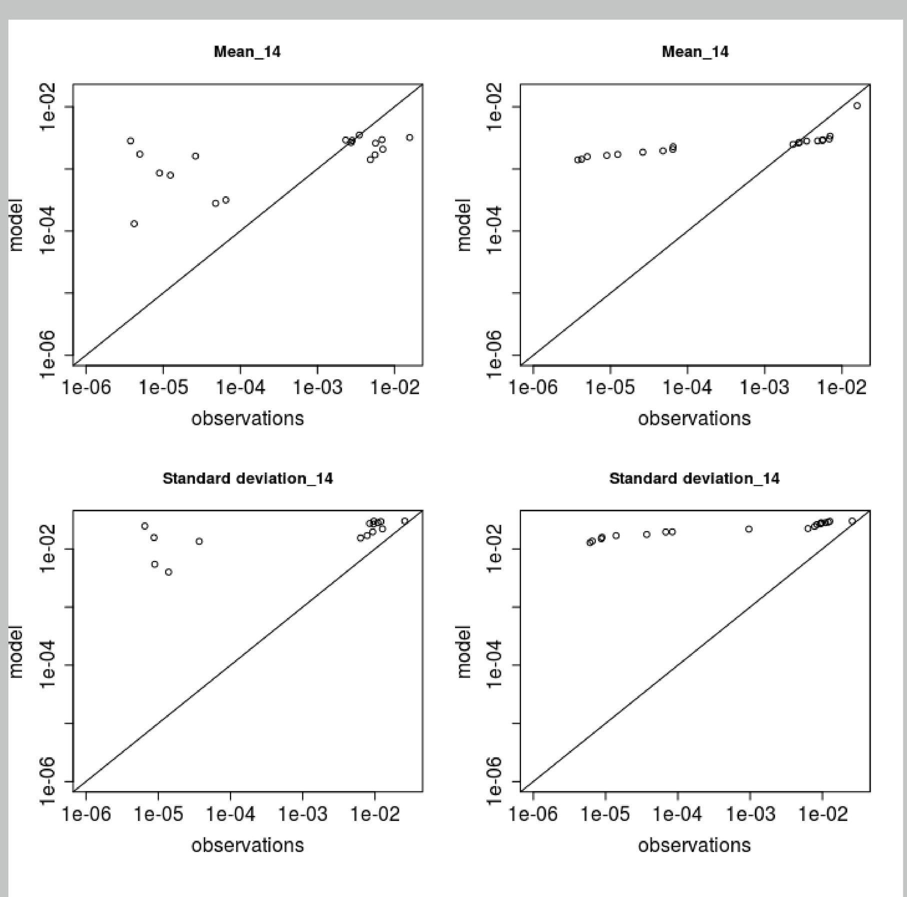

Figure: *Scatter-plot* (left) and *qq-plot* (right) for Trial 14 (neutral conditions) (g/m^3)

References

- Ferrero, E.; Mortarini, L.; Purghé, F. A Simple Parametrization for the Concentration Variance Dissipation in a Lagrangian Single-Particle Model. Bound. Layer Meteorol. 2017, 163, 91–101.
- Ferrero, E.; Manor, A.; Mortarini, L.; Oettl, D. Concentration Fluctuations and Odor Dispersion in Lagrangian Models, Atmosphere, 2020, 11, 27
- Ferrero, E., & Maccarini, F. (2021). Concentration fluctuations of single particle stochastic lagrangian model assessment with experimental field data. Atmosphere, 12(5)

Trial45

Table: Statistical analysis for the mean concentration and the concentration standard deviation in the unstable case Trial45. m indicates measured and c calculated.

Trial45

	mean m (g/m^3)	mean c (g/m^3)	FB	NMSE	R	FAC2 (%)	FAC5 (%)
MEAN	**0.0001**	**0.0009**	**−1.58**	**8.82**	**0.93**	**17**	**58**
STD	**0.0005**	**0.0052**	**−1.68**	**14.10**	**0.16**	**17**	**42**

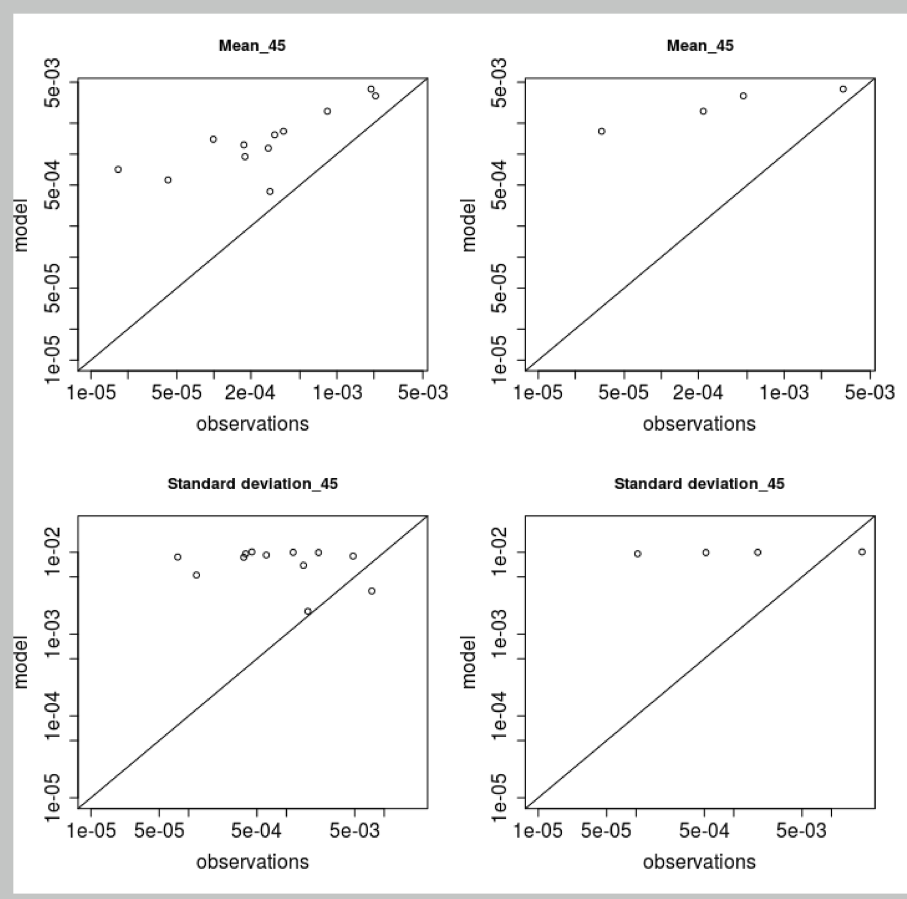

Figure: *Scatter-plot* (left) and *qq-plot* (right) for Trial 45 (unstable conditions) (g/m^3)

Trial 46

Table: Statistical analysis for the mean concentration and the concentration standard deviation in the neutral case Trial46. m indicates measured and c calculated.

Trial46

	mean m (g/m^3)	mean c (g/m^3)	FB	NMSE	R	FAC2 (%)	FAC5 (%)
MEAN	**0.0023**	**0.0019**	**0.21**	**5.23**	**0.62**	**17**	**29**
STD	**0.0059**	**0.0022**	**0.89**	**6.02**	**0.54**	**12**	**24**

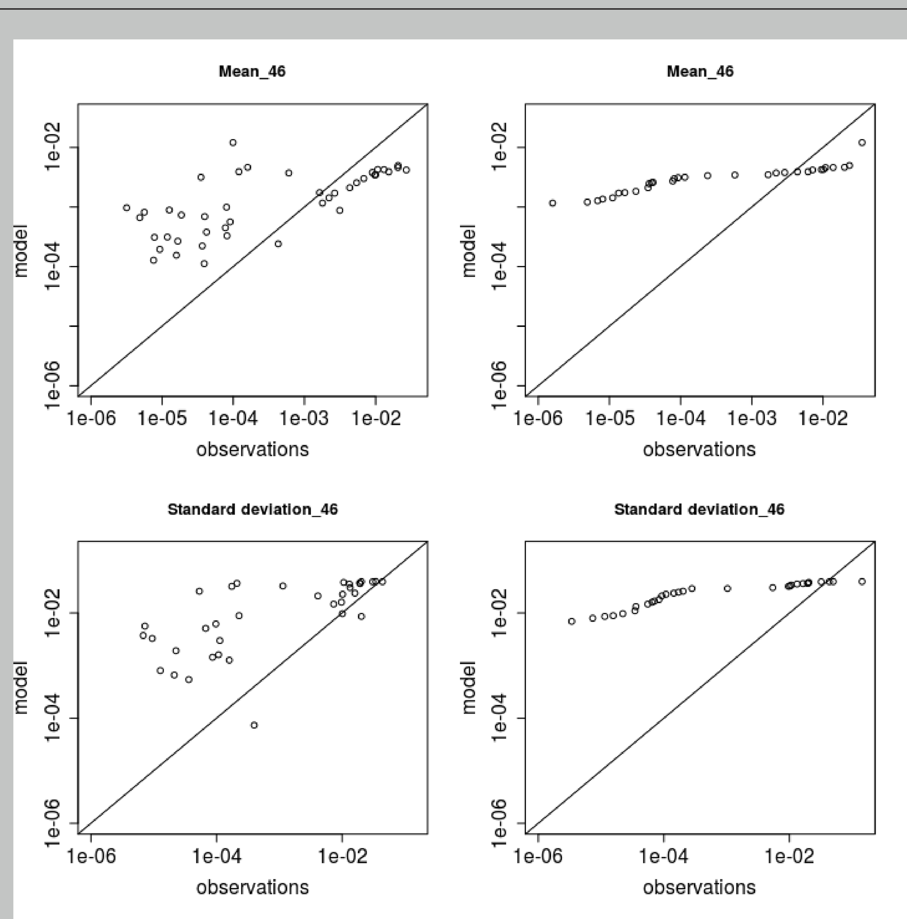

Figure: *Scatter-plot* (left) and *qq-plot* (right) for Trial 46 (neutral conditions) (g/m^3)

Source of concentrration variance

An expression for the source $Q_v(\mathbf{r})$ of the concentration variance $\overline{c^2}$, where c is the concentration fluctuation, can be prescribed by observing the Reynolds Averaged Equation (RAE) for concentration variance, in which a source term appears:

$$Q_v(\mathbf{r}) = 2\sigma_i^2 T_{L_i}\left(\frac{\partial \overline{C}}{\partial x_i}\right)^2$$

where $\sigma_i = \sigma_u, \sigma_v, \sigma_w$; $T_{L_i} = T_{L_u}, T_{L_v}, T_{L_w}$ are the three components of the Lagrangian time-scale and $\overline{C}(x, y, z, t)$ is the mean concentration. In Equation 1 the Einstein notation is assumed.

The concentration variance dissipation can be expressed with an exponential decay formula:

$$\frac{d\overline{c^2}}{dt} = -\frac{\overline{c^2}}{t_d}$$

where the term $t_d(z)$ is the *decay time-scale.*

As far as velocity standard deviations and Lagrangian time-scale are concerned, the widely used Hanna (1982) parameterizations is tested, while as for the decay time parameterization we follow Ferrero et al 2017.