Numerical modelling of passive tracer dispersion from a continuous source in a steady slope wind

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DISPERSION MODELLING IN COMPLEX TERRAIN

Contrairly to flat terrain, very few solutions are available in the literature for preliminary assessment of the fate of pollutants released in thermally driven flows over complex terrain. Such solutions are of utmost importance for many practical situations including not only pollutant species but also precursors, biogenic substances (pollens, seeds, spores etc.) and water vapor. Our objective is the simulation and simplified theoretical description of the **dispersion of a passive tracer from a continuous point source in a steady thermally driven diurnal slope wind.**

FORMULATION OF THE PROBLEM

In Eulerian modelling of dispersion, the concentration field evolution is described through the Reynold averaged instantaneous **mass balance equation for a passive tracer**:

$$\frac{\partial \overline{c_i}}{\partial t} + \overline{u_j}\frac{\partial \overline{c_i}}{\partial x_j} = \frac{\partial}{\partial x_j} K_{jj} \frac{\partial \overline{c_i'}}{\partial x_j} + \overline{R_i} + \overline{E_i} - \overline{S_i}$$

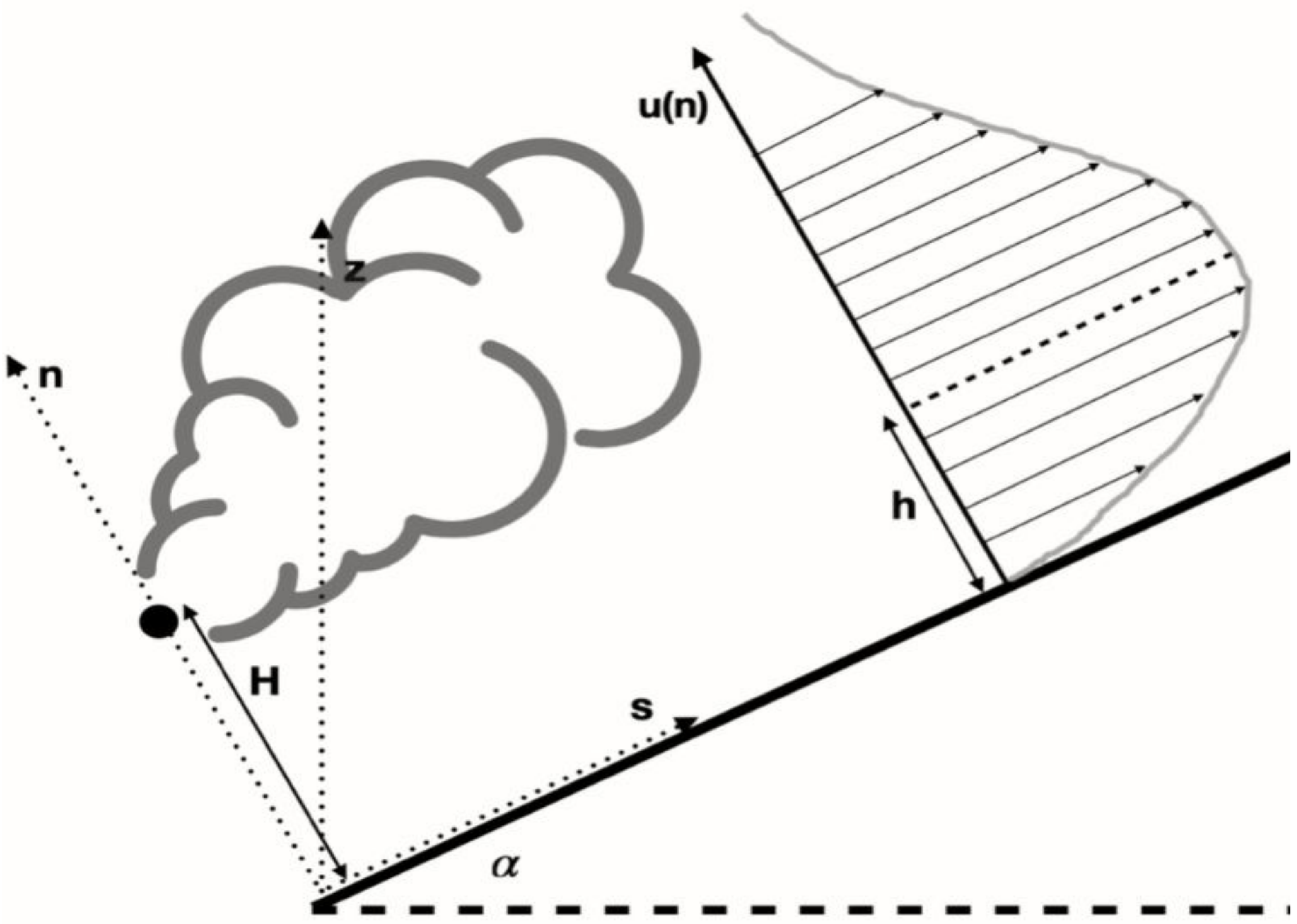
where the terms are:
- mean concentration in time
- advection by mean wind
- turbulent transport
- chemical reactions
- emissions
- sinks

Thermally driven anabatic slope flow described with the **Prandtl model (1942)**.

$$\begin{cases} \frac{\partial \overline{u}}{\partial t} = \overline{\theta}\frac{N^2}{\gamma} sin\alpha - K_m \frac{\partial^2 \overline{u}}{\partial n^2} \\ \frac{\partial \overline{\theta}}{\partial t} = \overline{-u}\gamma sin\alpha + K_h \frac{\partial^2 \overline{\theta}}{\partial n^2} \end{cases}$$

⇓

$$\begin{cases} \overline{u} = \Theta \frac{N}{\gamma} Pr_t^{-1/2} e^{-n/l} sin(n/l) \\ \overline{\theta} = \Theta e^{-n/l} cos(n/l) \end{cases}$$



Boundary conditions:

- Reflection or deposition on the lower boundary
- Transparency on the right and higher boundary
- Continuous source on the left boundary

Choice of the **eddy diffusion coefficient K**:

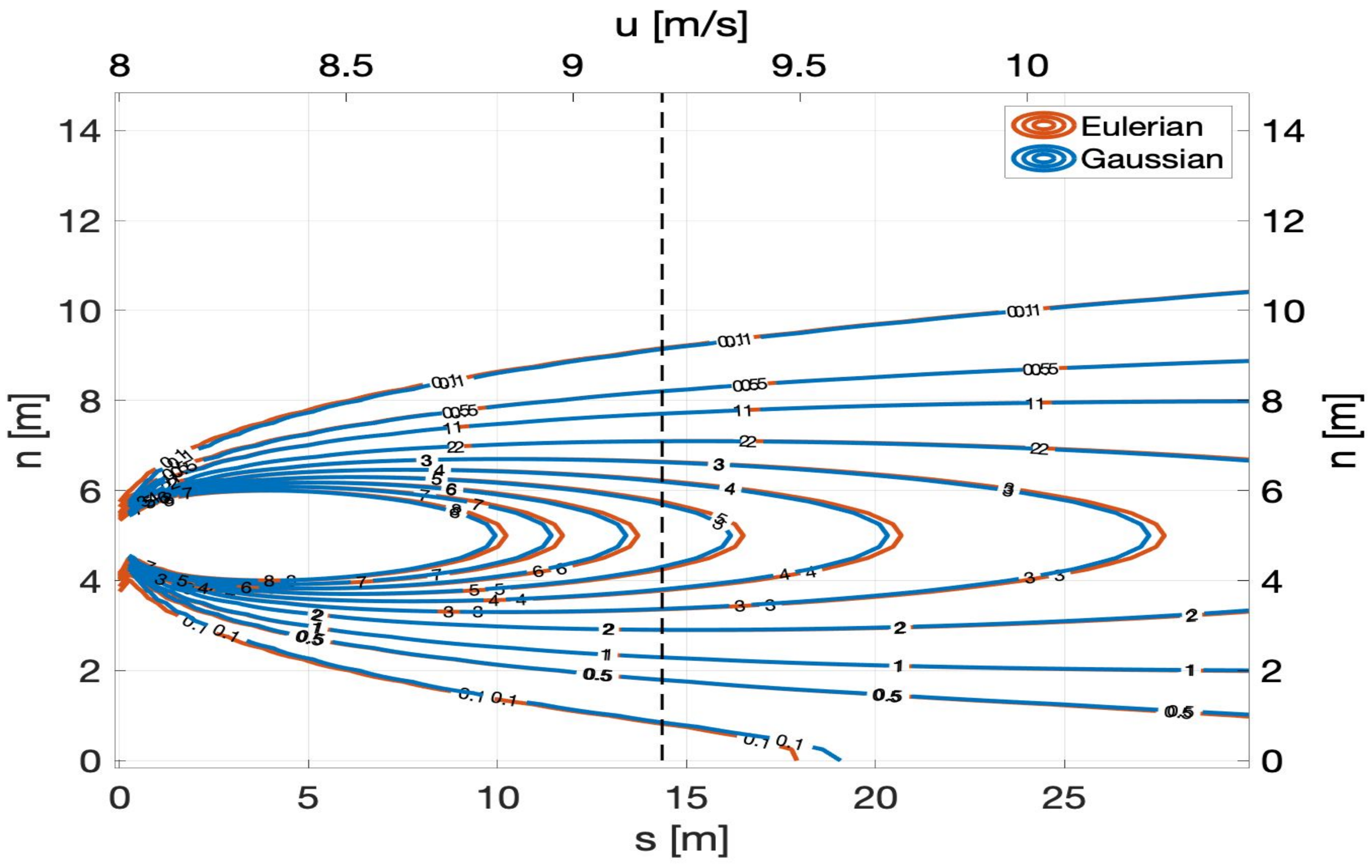
forcing

$$K = 2c^2 \frac{\Delta T_s^2 g\beta}{N\gamma \sin\alpha}$$

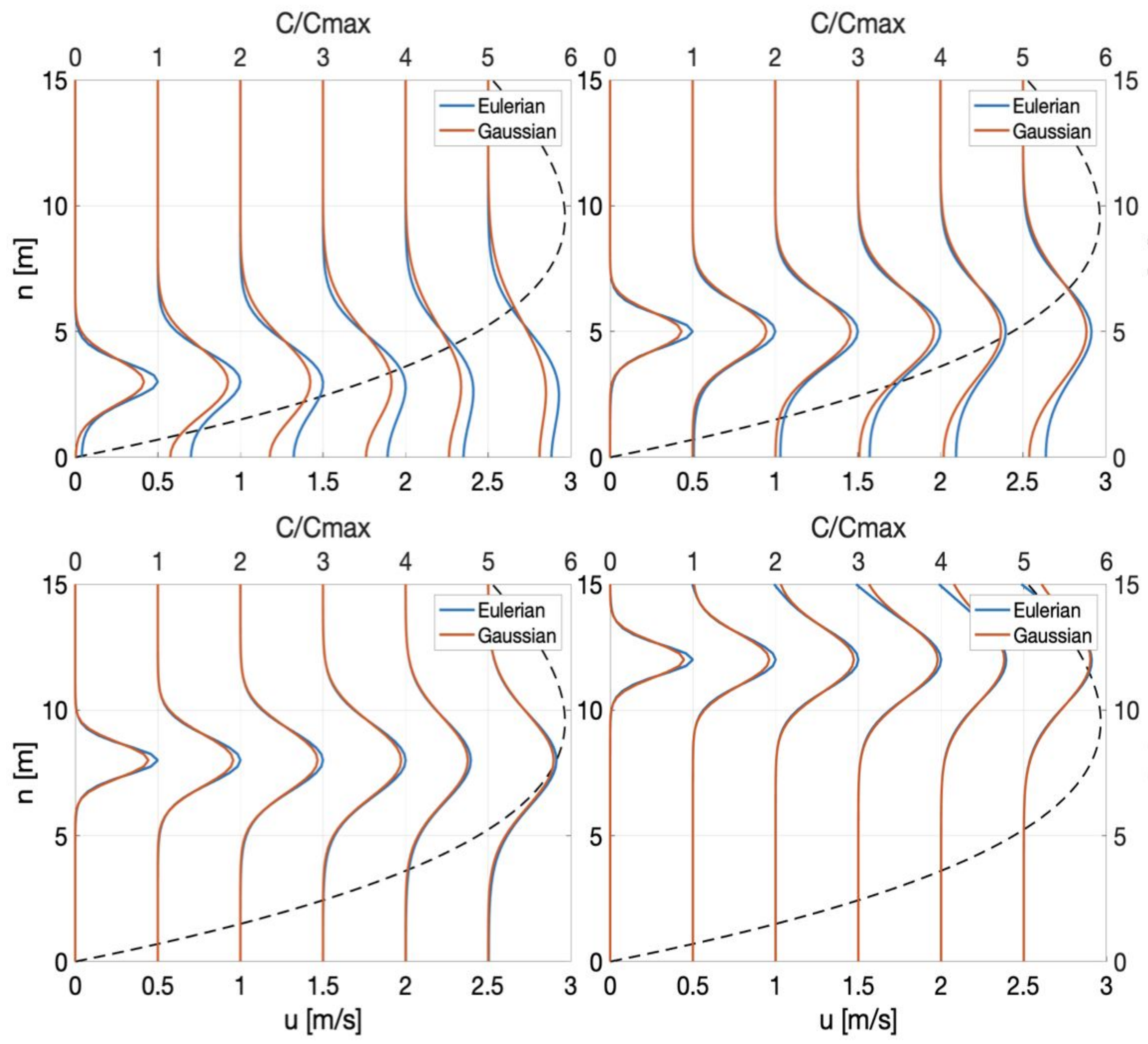
environmental conditions — slope conformation

RESULTS

Validation of the model for the constant u profile case



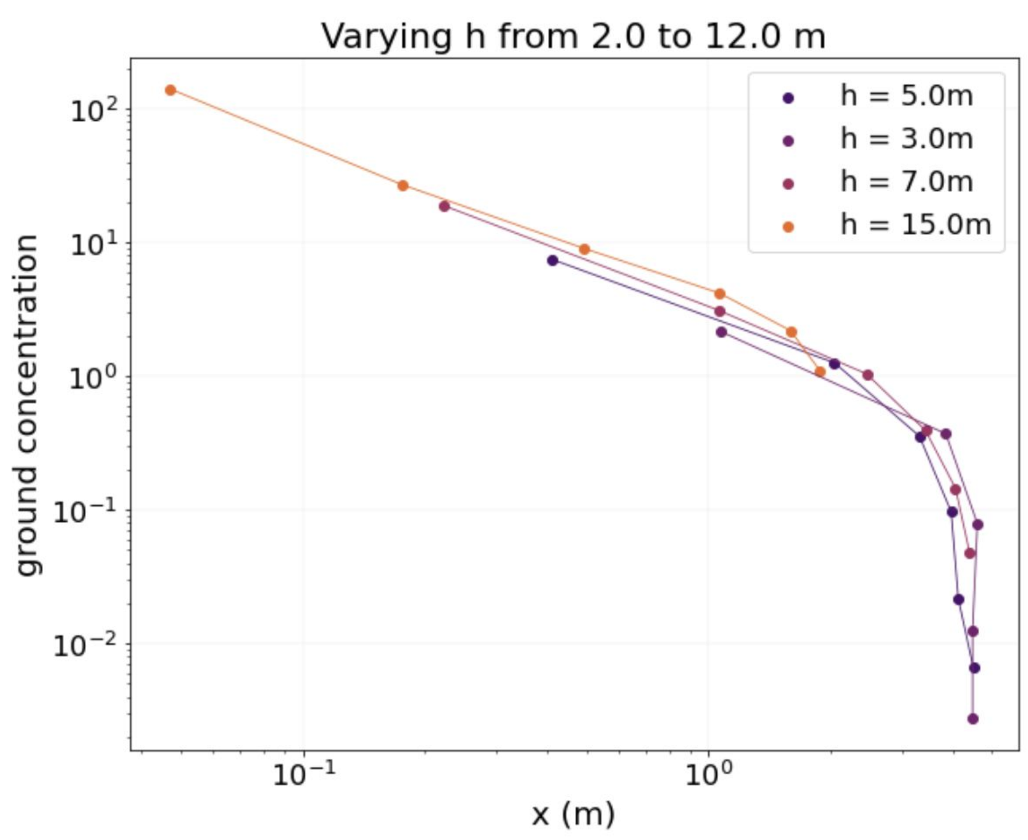
Comparison between the concentration fields obtained with a Gaussian model for u=u(H), H being the height of the source, and with the Eulerian for constant upslope wind profile and varying source height H.



The closer the source height is to the intensity peak of the slope wind and to the lower boundary, the higher the error due to the use of a Gaussian approach.

The same behavior is observed when varying the slope wind profile through the variation of the environmental conditions and keeping the source height constant.

CONCLUSIONS



The use of a Gaussian model to estimate the concentrations (especially closer to the ground) does not give accurate results.

A relationship between the position and the intensity of the ground concentration maximum, independent from the height of the intensity peak, is evidenced.

References: Prandtl L. 1942. Führer durch die Strömungslehre, Chapter 5. Vieweg und Sohn: Braunschweig, Germany. [English translation: Prandtl L. 1952. Mountain and valley winds in stratified air, in Essentials of Fluid Dynamics: 422–425. Hafner Publishing Company: New York, NY]