SIANI
INSTITUTO UNIVERSITARIO
INGENIERIA COMPUTACIONAL

Application of genetic algorithms for the calibration of an air quality model and its validation using pollutant measures from the surroundings of an electric power plant

J. Ramírez [1], A. Oliver [1], E. Rodríguez [1]

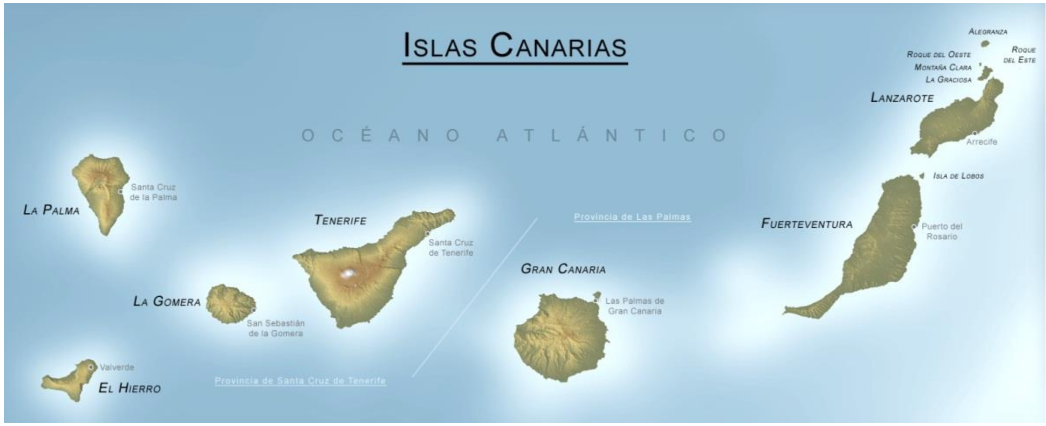
[1] University Institute SIANI, University of Las Palmas de Gran Canaria, Spain

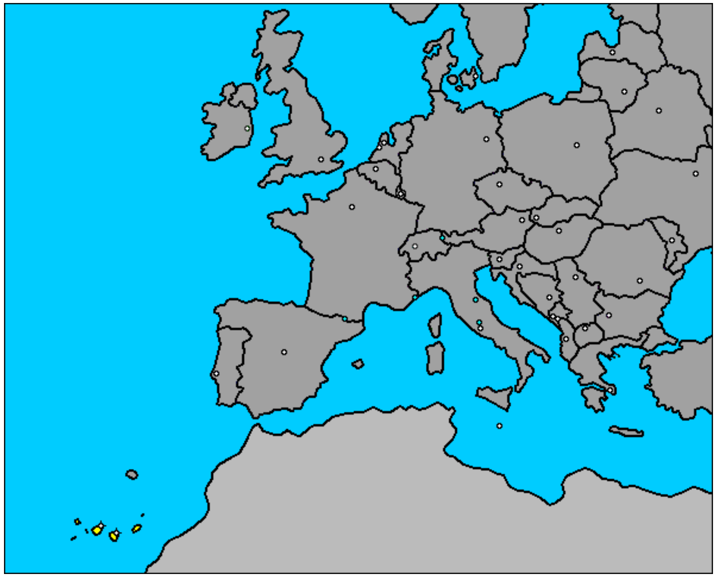
UNIVERSIDAD DE LAS PALMAS
DE GRAN CANARIA

UNIVERSIDAD DE LAS PALMAS
DE GRAN CANARIA

Motivation

- Validation of the framework proposed by the authors (Oliver et al. 2013, Energy) through experimental data from an electric power plant
- Gran Canaria island (Canary Islands)





Motivation

- Two different stages: Modeling and Calibration – Two kinds of data are needed:

1) Wind data

2) Pollutant concentration data

Motivation

- WIND DATA: For modeling and calibration

- Wind data from 1 station close to power plant
- Wind data from forecasting model
- 3 consecutive days of wind data (hourly)
- Calibration of mode through genetic algorithms

Motivation

○Pollutants data: Some data for modeling and other for calibrating

- One emission stack (Electric power plant) (modeling)
- 3 immission stations (calibration)
- 1 inmission station (validation)
- 3 consecutive days of emission and immission data (hourly)
- Calibration of model variables attending experimental data from **immission**

Algorithm

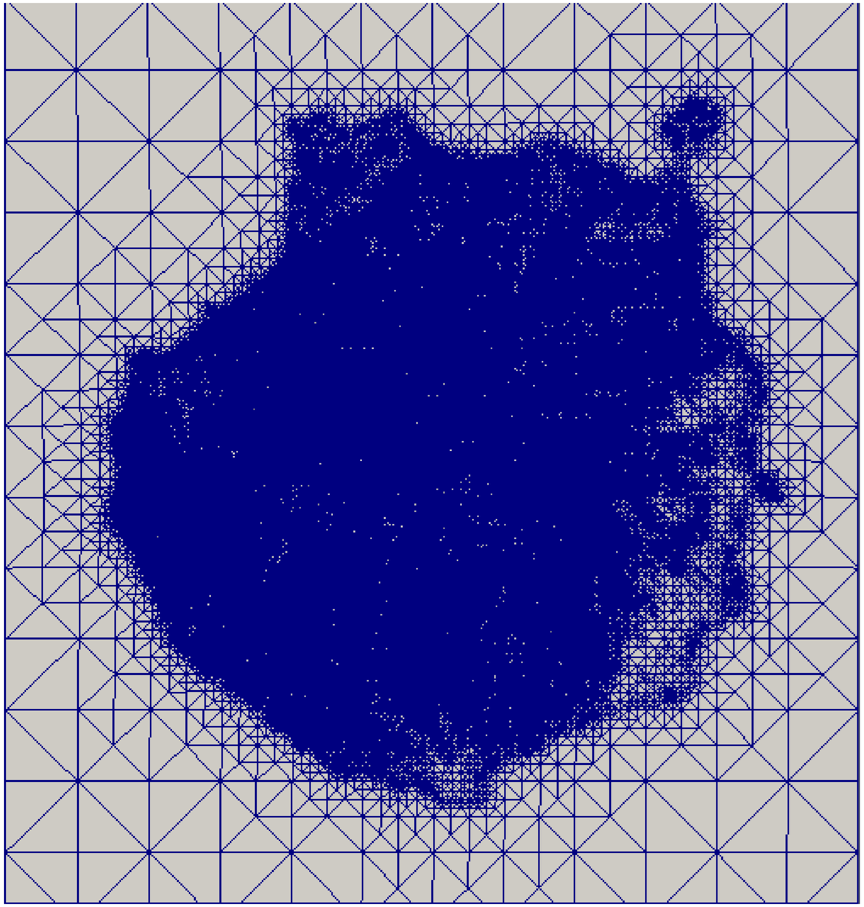
SIANI

Adaptive Finite Element Model

- Construction of a tetrahedral mesh adapted to the terrain
- Wind field modeling from experimental and meteorological data
- Pollutant dispersion modeling

Mesh construction

Gran Canaria Mesh

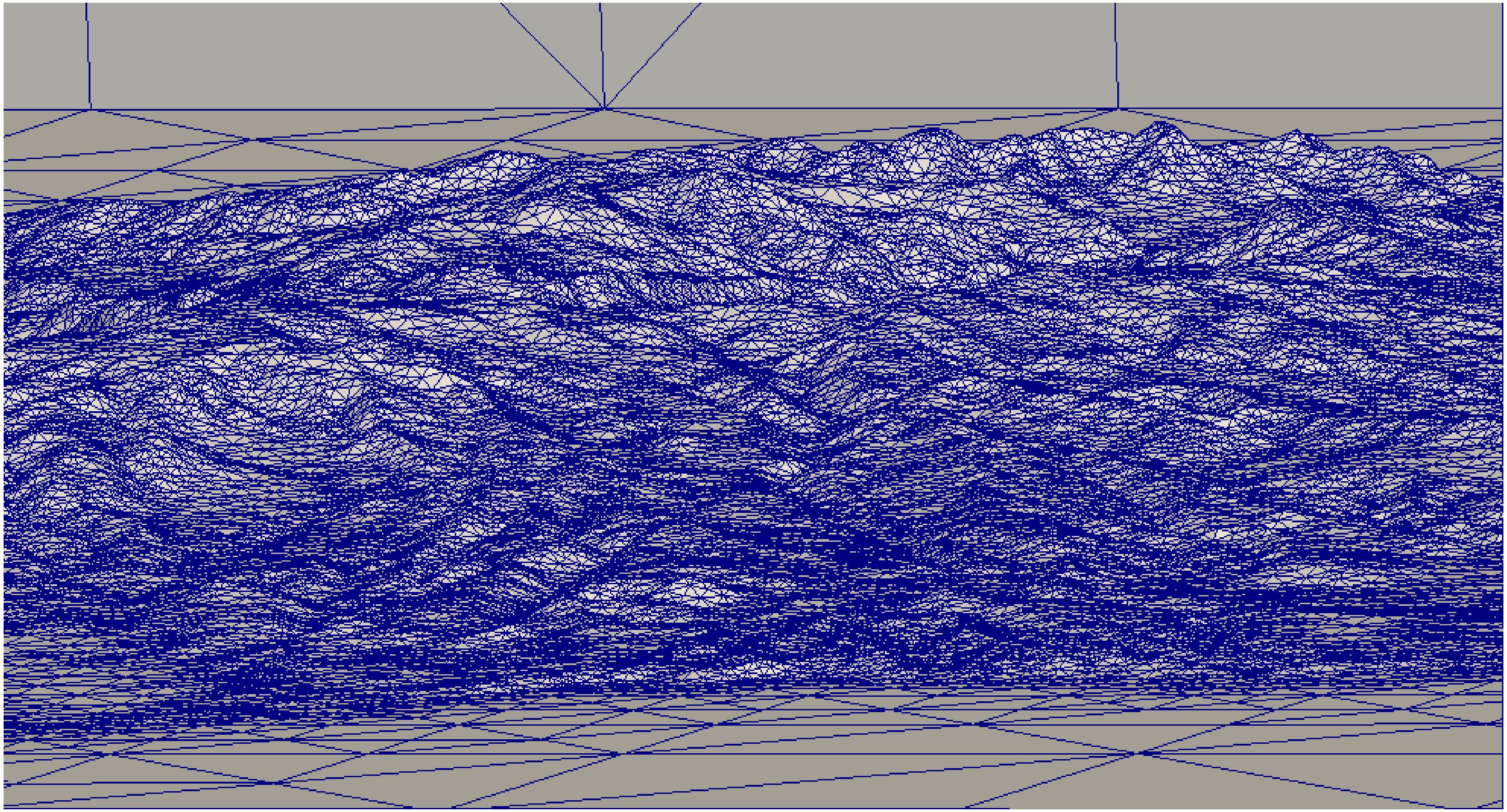


Mesh construction

Gran Canaria Mesh (II)

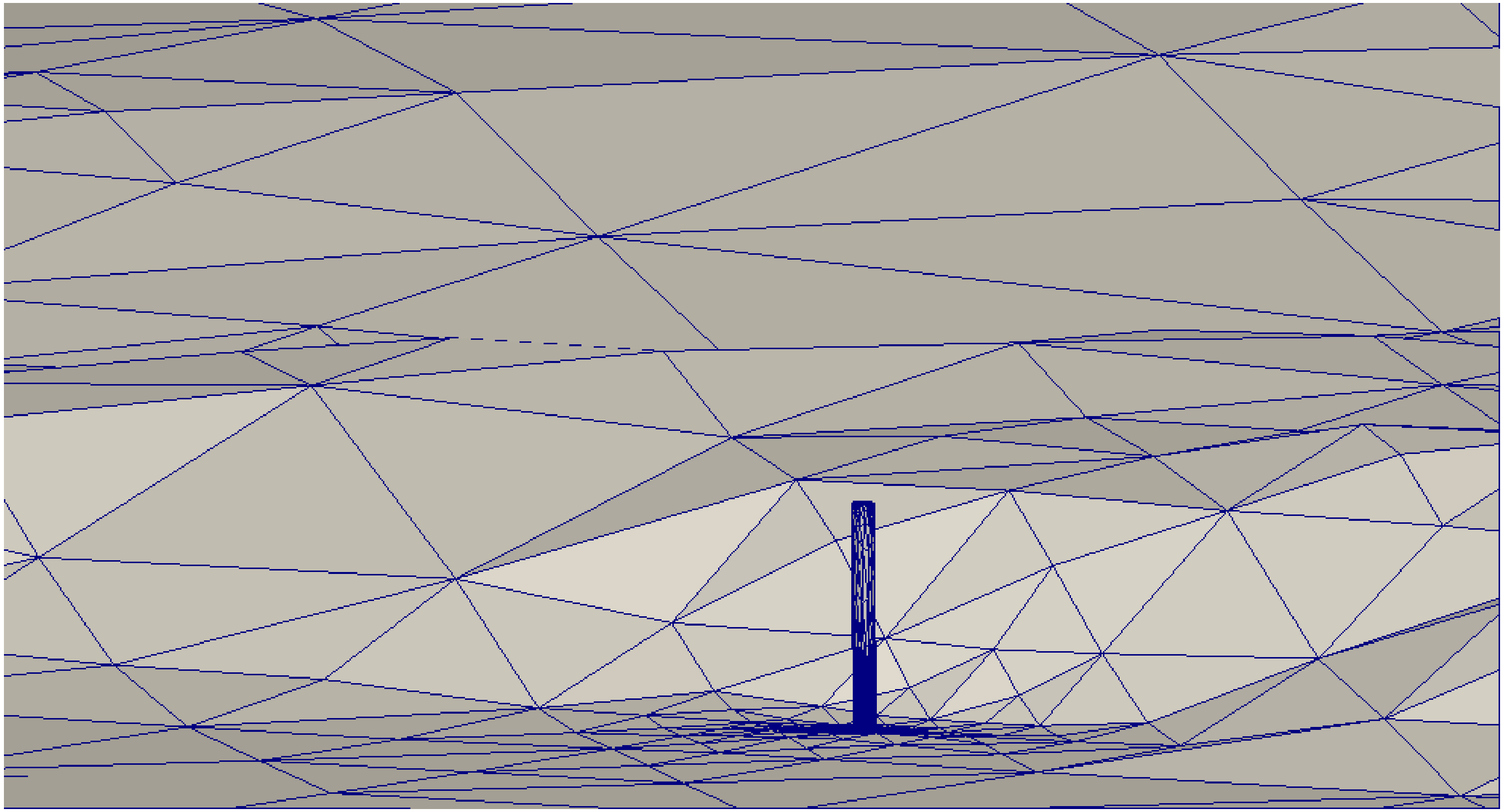
Mesh construction

Gran Canaria Mesh



Adaptative Mesh

Gran Canaria Mesh



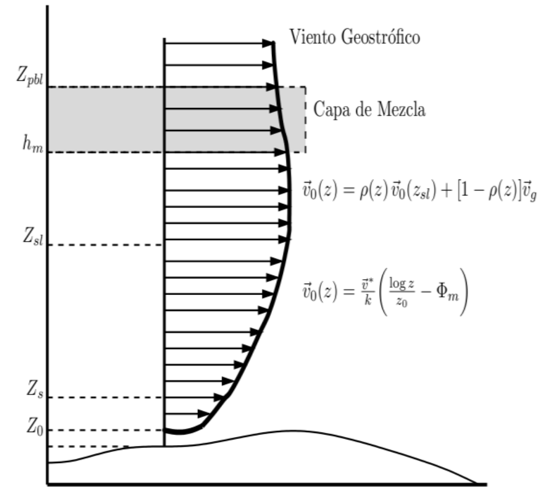
Wind field modeling

- Experimental data from 1 station (power plant)
- Use Harmonie model

- Horizontal interpolation
  - Weighting inverse to the squared distance and inverse height differences

$$\tilde{\mathbf{v}}_0(z_m) = \varepsilon \frac{\sum_{n=1}^{N} \frac{\tilde{\mathbf{v}}_n}{d_n^2}}{\sum_{n=1}^{N} \frac{1}{d_n^2}} + (1-\varepsilon) \frac{\sum_{n=1}^{N} \frac{\tilde{\mathbf{v}}_n}{|\Delta h_n|}}{\sum_{n=1}^{N} \frac{1}{|\Delta h_n|}}$$

- Vertical interpolation
  - Log-linear wind profile



Wind field modeling

- The resulting mass-consistent wind field $\mathbf{u}$ verifies:

$$\nabla \cdot \mathbf{u} = 0 \quad \text{in } \Omega$$
$$\mathbf{n} \cdot \mathbf{u} = 0 \quad \text{on } \Gamma_a$$

and minimizes the adjusting functional

$$E(\mathbf{v}) = \frac{1}{2} \int_{\Omega} (\mathbf{v} - \mathbf{u}_0)^t \, \mathbf{P} \, (\mathbf{v} - \mathbf{u}_0) \, d\Omega$$

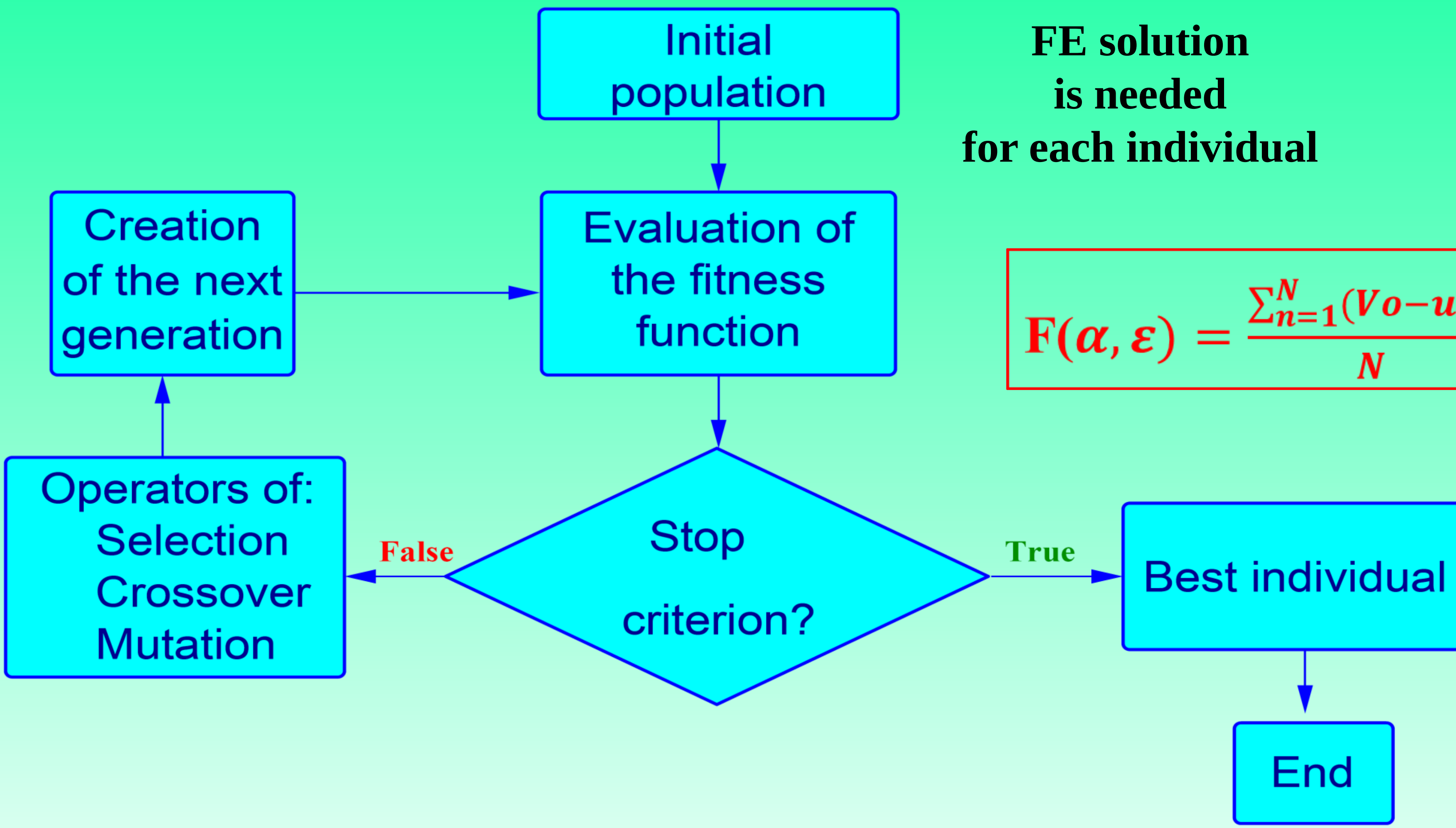
- Introducing a Lagrange multiplier and solving an elliptic problem

Wind field Calibration

- Calibration
  - ε (Horizontal interpolation weight)
  - Tv Th (Mass consistent factors, $\alpha = \frac{Th}{Tv}$)

- Genetic algorithms
  - *G. Montero, E. Rodriguez, R. Montenegro, J.M. Escobar, J.M. Gonzalez-Yuste,* ***Genetic algorithms for na improved parameter estimation with local refinement of tetrahedral meshes in a wind model****, Advances in Engineering Software, Volume 36, Issue 1, January 2005, Pages 3-10, ISSN 0965-9978, [DOI:10.1016/j.advengsoft.2004.03.011]*

Wind field Calibration



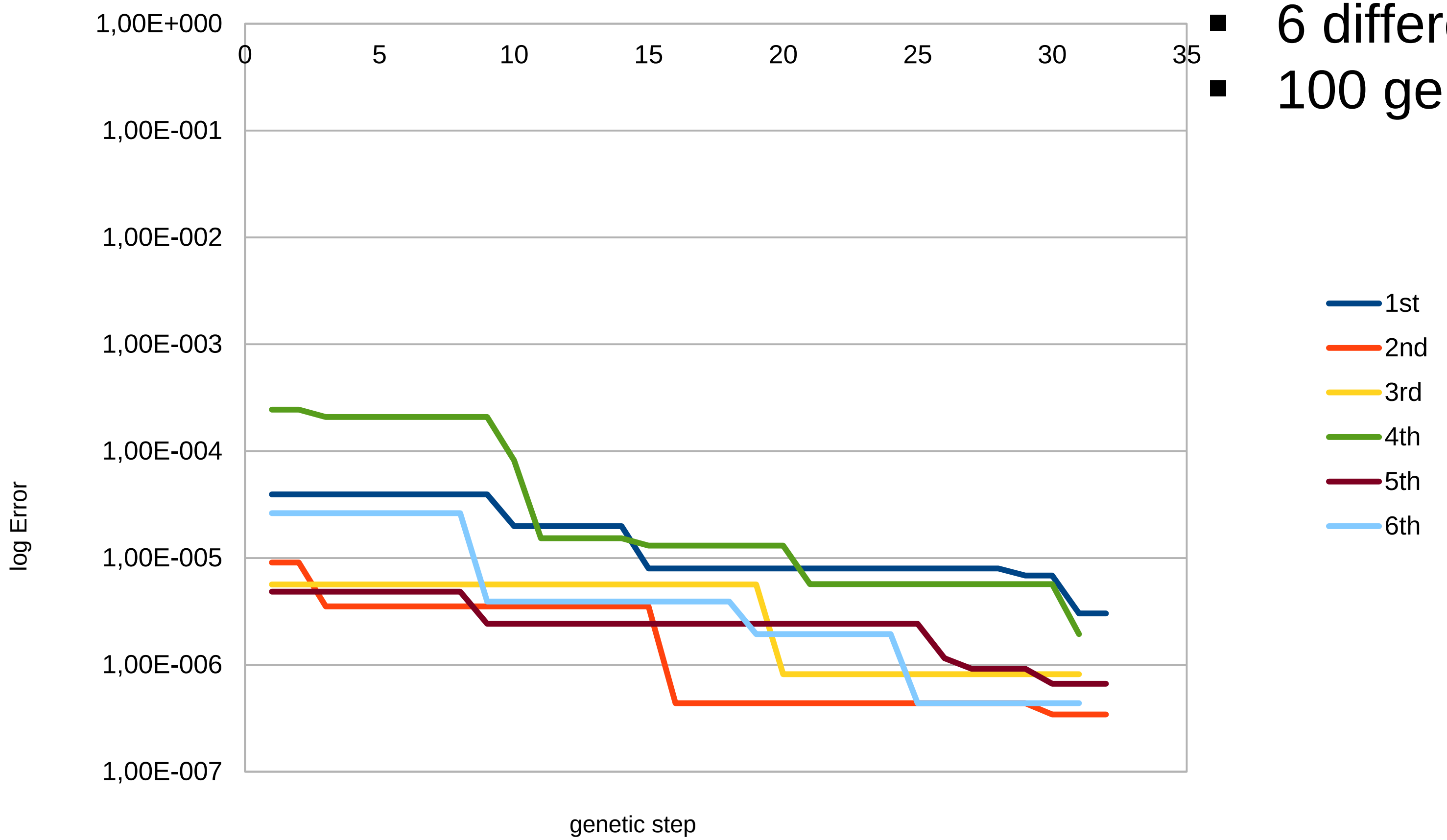
FE solution
is needed
for each individual

$$\mathbf{F}(\alpha, \varepsilon) = \frac{\sum_{n=1}^{N} (Vo-u)_n^2}{N}$$

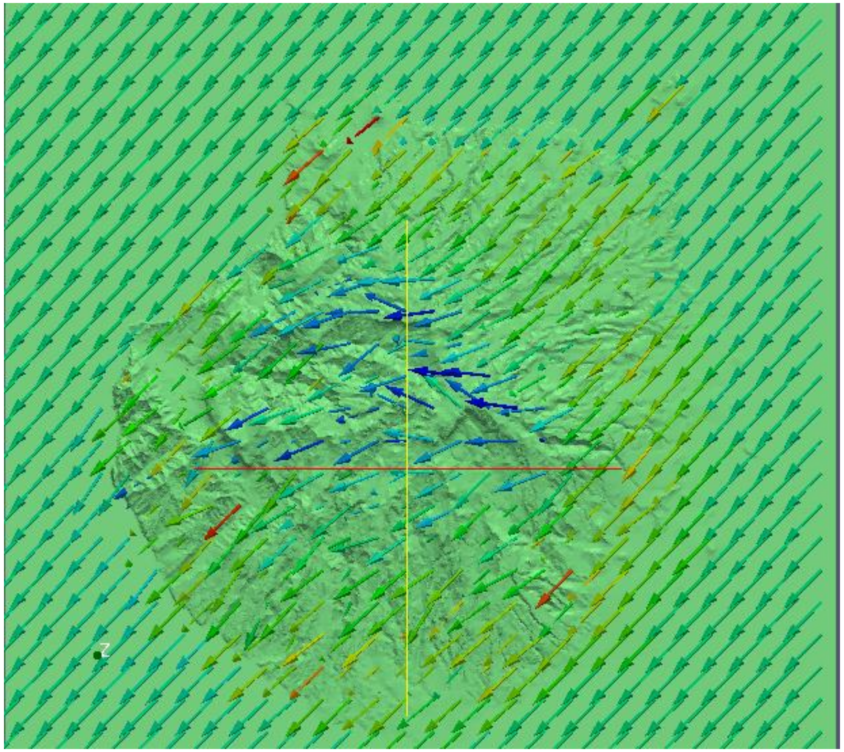
Wind field Calibration

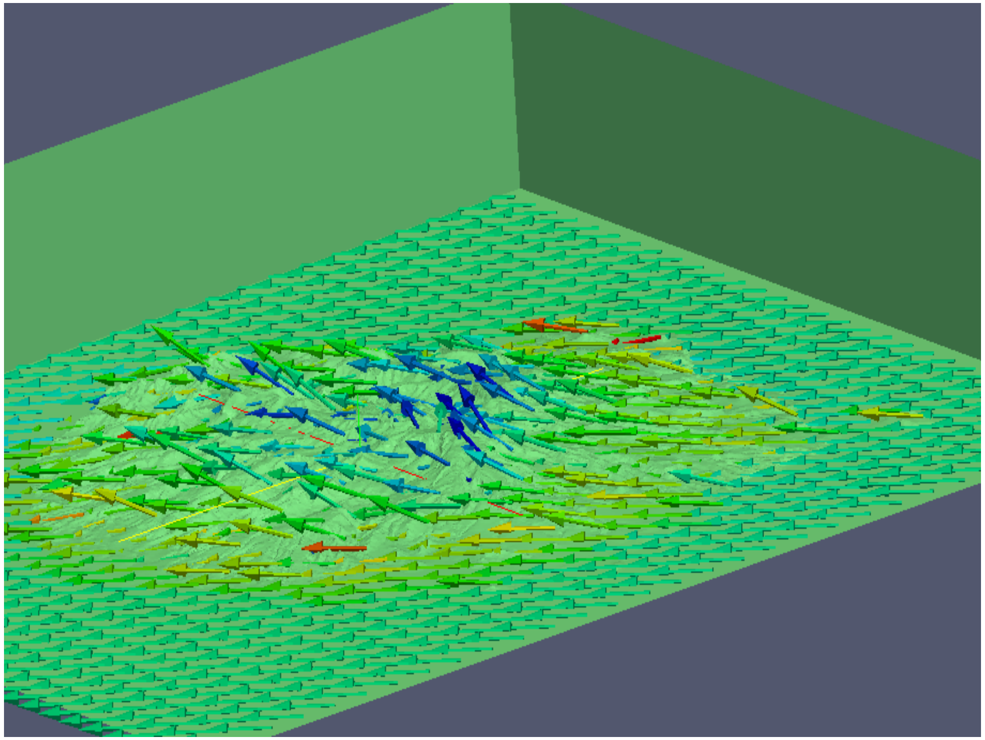
- Genetic Algorithm evolution

- Initial population 1000
- 6 different episodes
- 100 genetic iterations



Wind field results





Air quality modeling

Find concentration $\mathbf{c}(\mathbf{x},t)$ for $(\mathbf{x}, t) \in \Omega \times (0, t^{end}]$

$$\frac{\partial \mathbf{c}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{c} = \nabla \cdot (\mathbf{K} \nabla \mathbf{c}) + \mathbf{e} + \mathbf{s}(\mathbf{c})$$

$c(x,t) = c^{emi}$ Stack outflow

$c(x,t) = c^{amb}$ Inlet wind boundaries

$n.\nabla c = 0$ Outlet wind boundaries

$c(x,0) = c^{ini}$ Initial condition

$n.k\nabla c = -V^d c$ Terrain condition (Vd is the deposition diagonal matrix)

Air quality modeling

- Temporal discretization: Cranck-Nicolson

- Spatial discretization: Least Squares FEM

- System solver: Conjugate gradient preconditioned with an Incomplete Cholesky Factorization

- Matrix storage: sparse MCS (matrix column storage)

Air quality
Calibration

- Calibration
  - Diffusion (K), minimization of F(k):

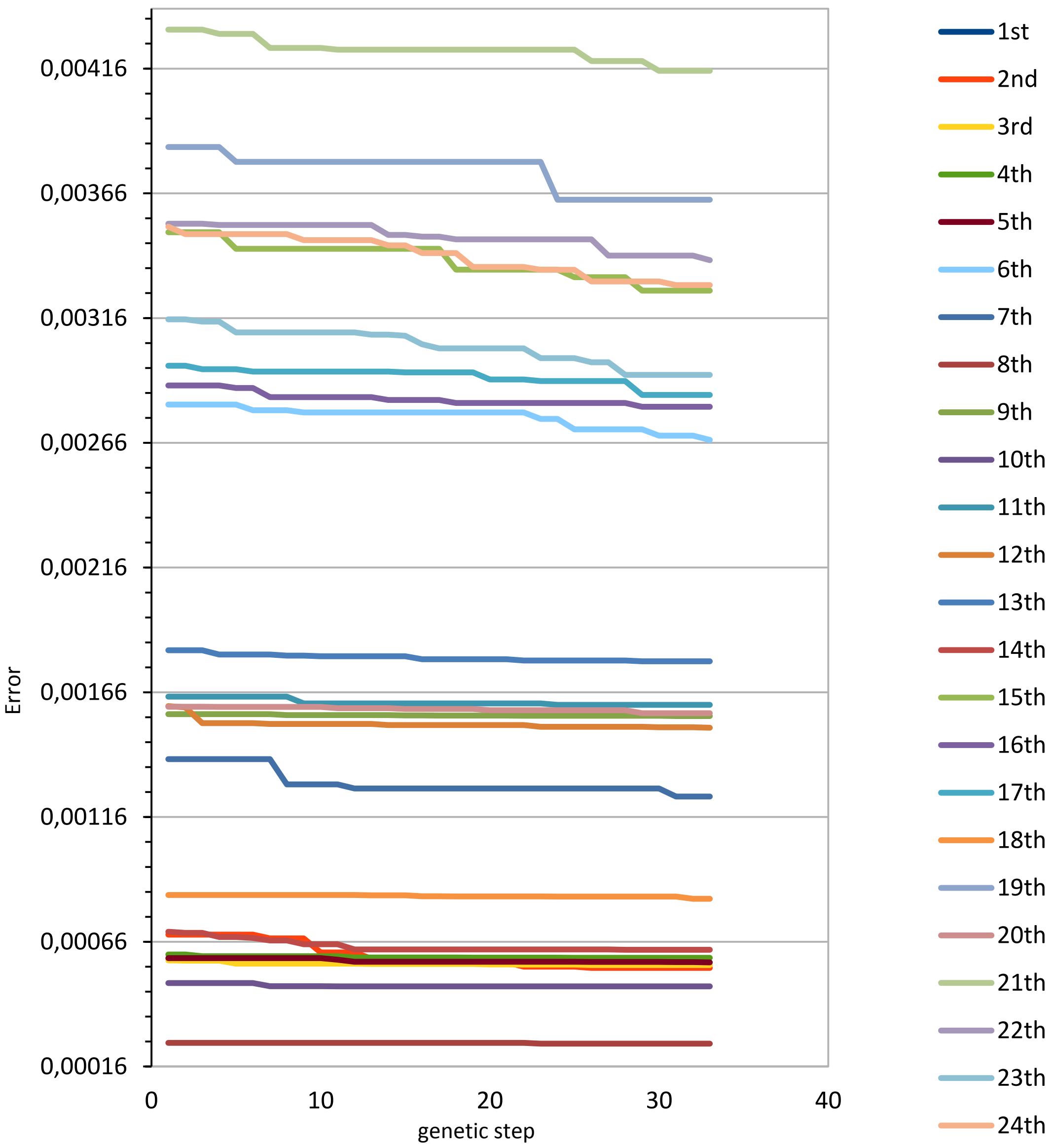
$$F(k) = RMSE = \sqrt{\frac{\sum_{n=1}^{N}(c - c_t)^2{}_n}{N}}$$

K = diffusion parameter
N= numer of stations
C = measured concentration in the station

c_t= Calculated concentration

Air quality Calibration

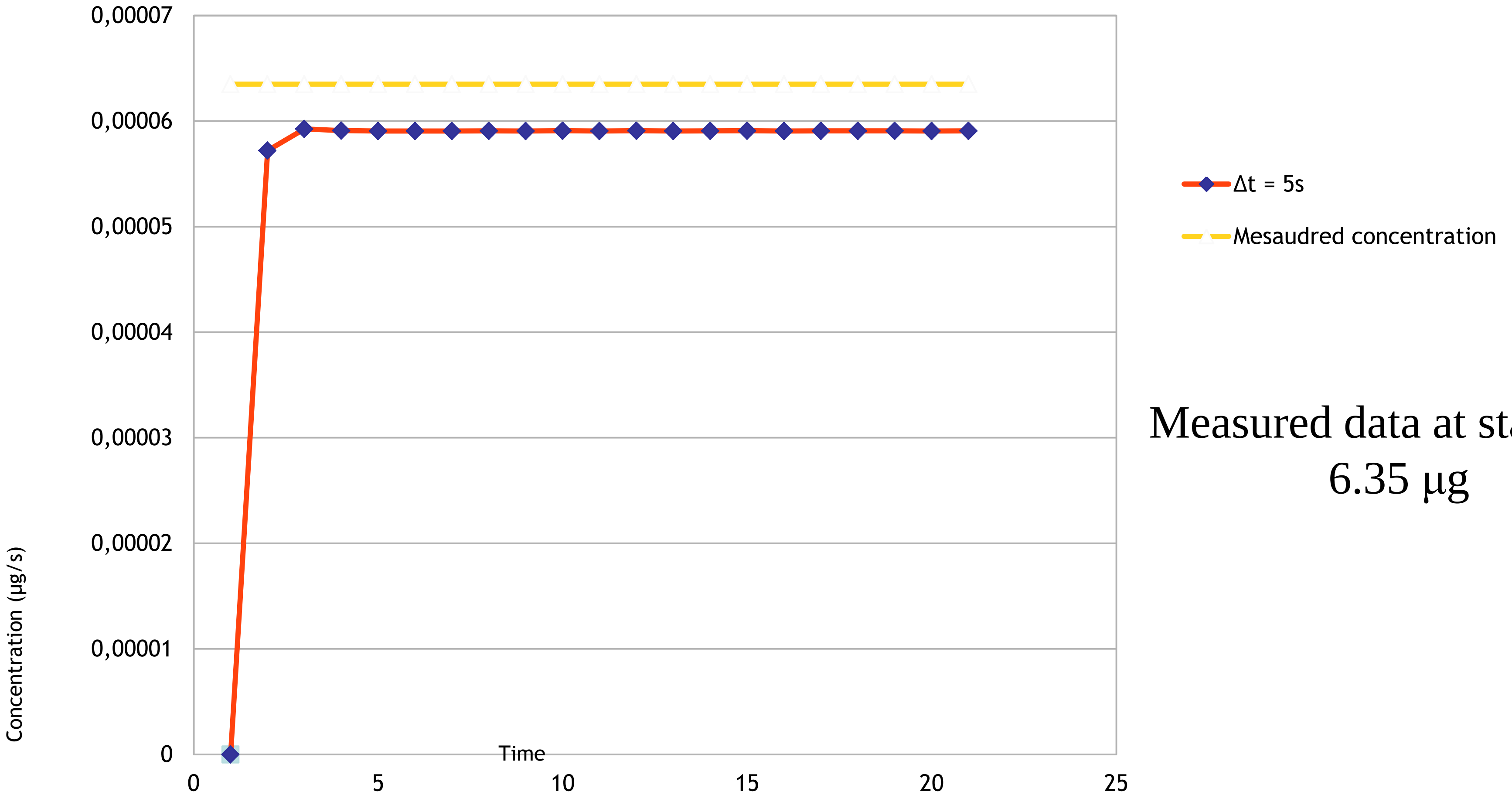
- Genetic algoritm evolution



- 24 hours simulation
- 64 individual population
- 32 genetic steps
- Based on 3 stations data

Air quality Validation

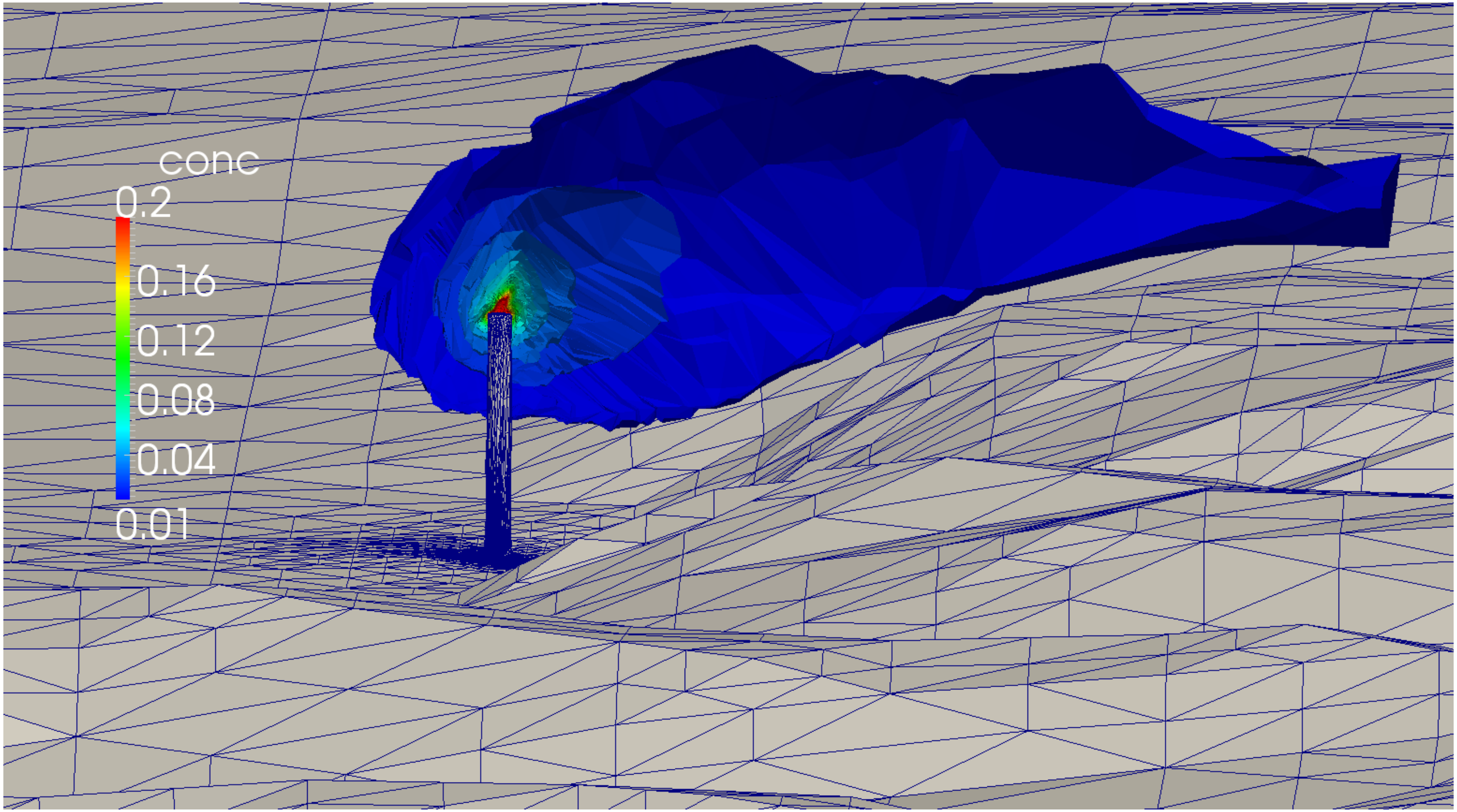
- Validation



Measured data at station 1: 6.35 µg

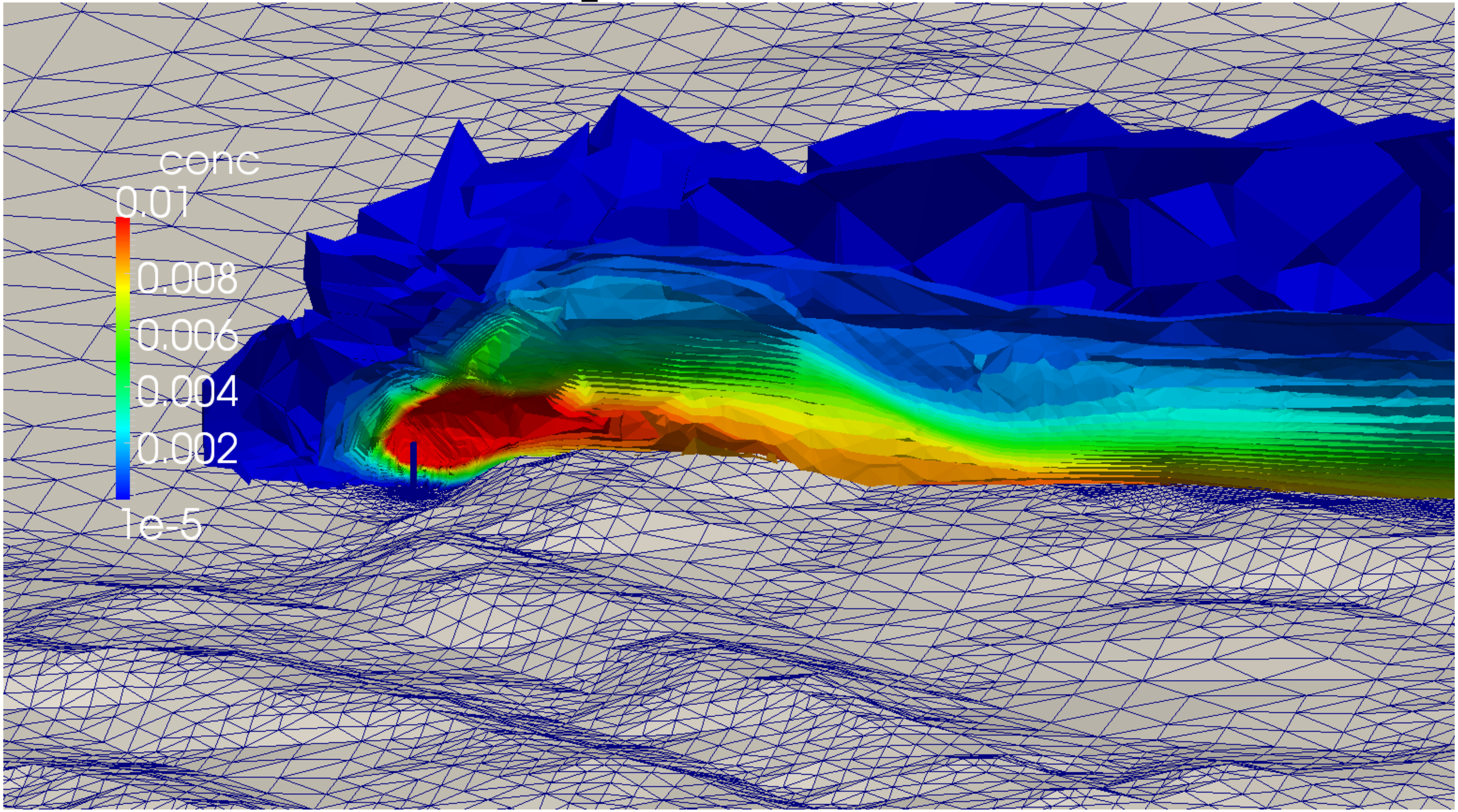
Air quality Results

Concentration SO_2 (g/m^3) after 1000 seconds



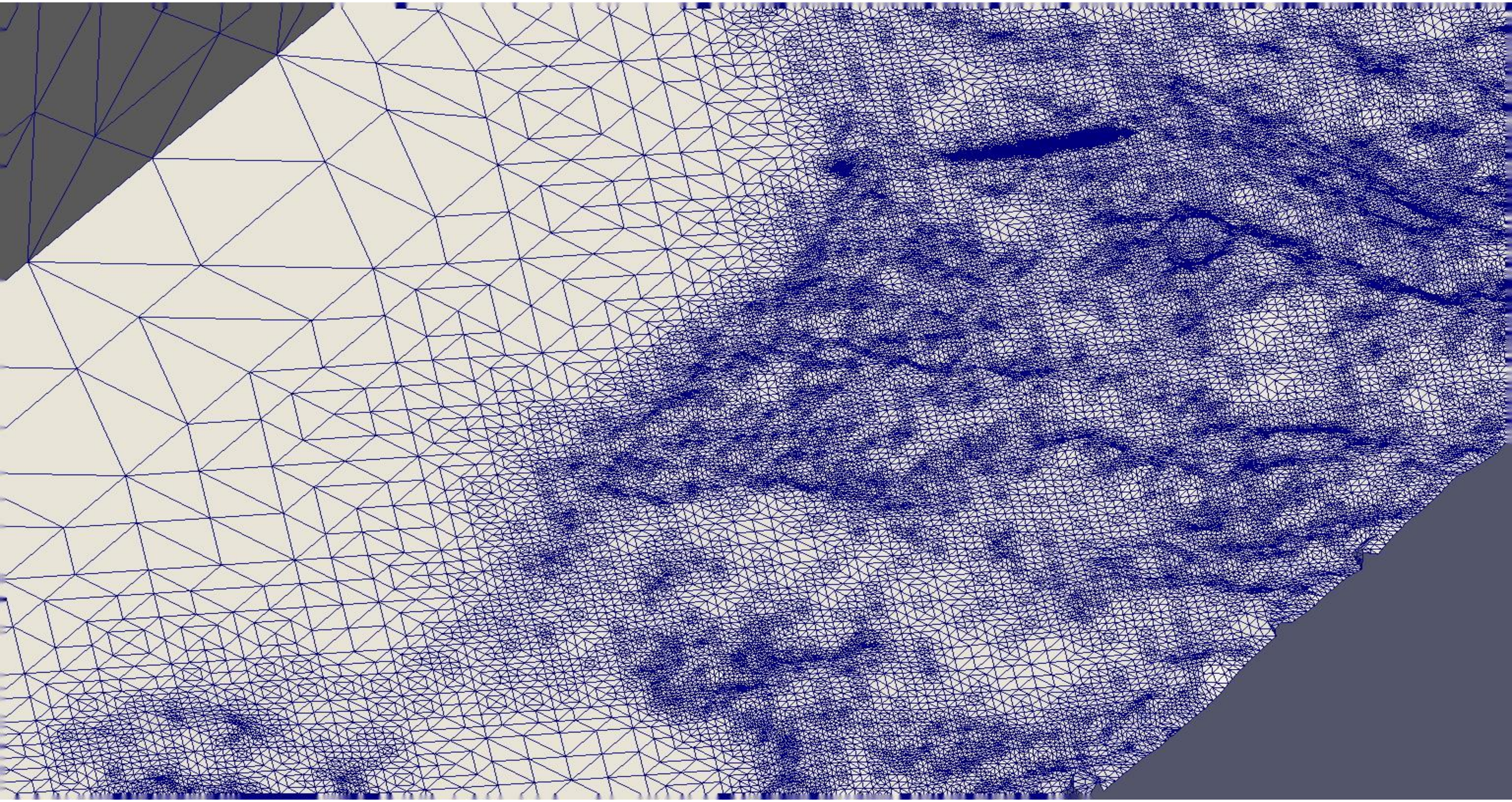
Air quality Results

Concentration $S0_2$ (g/m^3) after 1000 seconds



Air quality Results

Isosurface evolution 1 µg/m^3



Conclusions

- Suitable approach for modeling air transport and reaction over complex terrains
  - A. Oliver, G. Montero, R. Montenegro, E. Rodríguez, J.M. Escobar, A. Pérez-Foguet, **Adaptive finite element simulation of stack pollutant emissions over complex terrains**, Energy, Volume 49, 1 January 2013, Pages 47-60, ISSN 0360-5442, http://dx.doi.org/10.1016/j.energy.2012.10.051.

- Genetic algorithms useful for calibration
- Validation comparing model outcomes with experimental data

Application of genetic algorithms for the calibration of an air quality model and its validation using pollutant measures from the surroundings of an electric power plant

J. Ramírez [1], A. Oliver [1], E. Rodríguez [1]

[1] University Institute SIANI, University of Las Palmas de Gran Canaria, Spain