University Institute of Intelligent Systems and Numerical Applications in Engineering

CEID Annual Seminar 2014, LUT, Lappeenranta University of Technology, 27th May, 2014, Lappeenranta, Finland

http://www.siani.es/

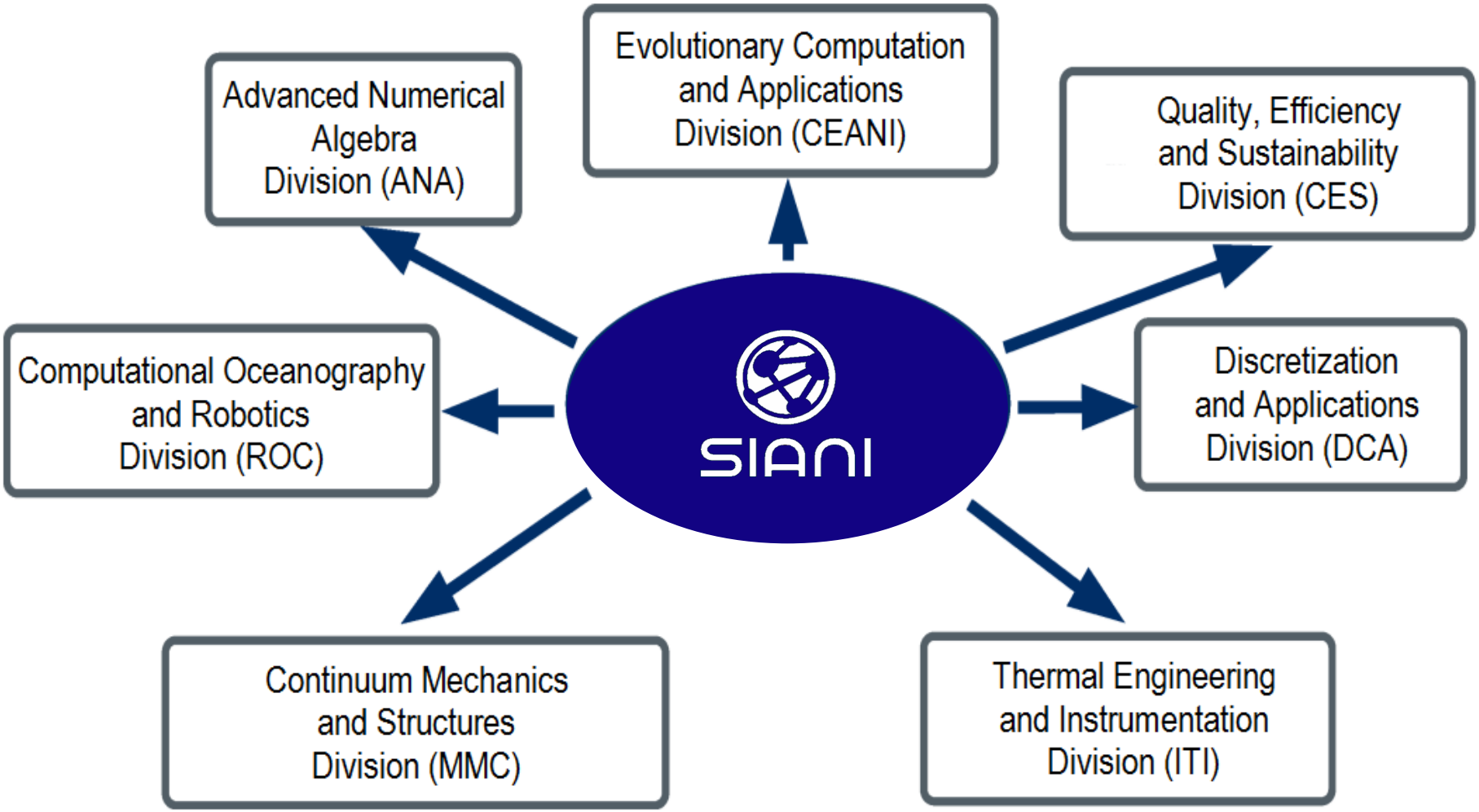
UNIVERSIDAD DE LAS PALMAS
DE GRAN CANARIA

Activities

- Research
- Techno-scientific publications
- Public and private support for Research and Development (R&D) Projects
- Training of research staff
- Official Research Master degrees
- Official Doctorate Program
- Organisation of scientific events
- Registrations and patents

Organisation and Structure

Research divisions



Activity

Wind fields, air pollution and solar radiation forecasting over complex terrains

Discretization and Applications

Advanced Numerical Algebra

MEC/MINECO and FEDER projects

REN2001-0925-C03
CGL2004-06171-C03
CGL2007-65680-C03
CGL2008-06003-C03
CGL2011-29396-C03-01

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http://www.dca.iusiani.ulpgc.es/proyecto2012-2014

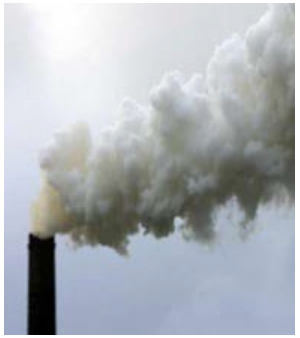
Research Lines

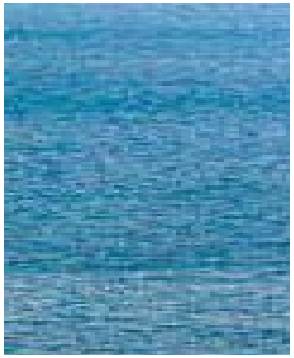
"Discretization and Applications" and "Advanced Numerical Algebra"

- Three-dimensional modeling and simulation of wind fields
- Automatic generation of triangle and tetrahedral meshes
- Solving large sparse systems of equations
- Combination of the wind model with forecasting meteorological models, air pollution and forest fires.
- Development of a solar radiation numerical model
- Numerical simulation of oil fields
- Parallel software
- Domotic systems.

Research Lines

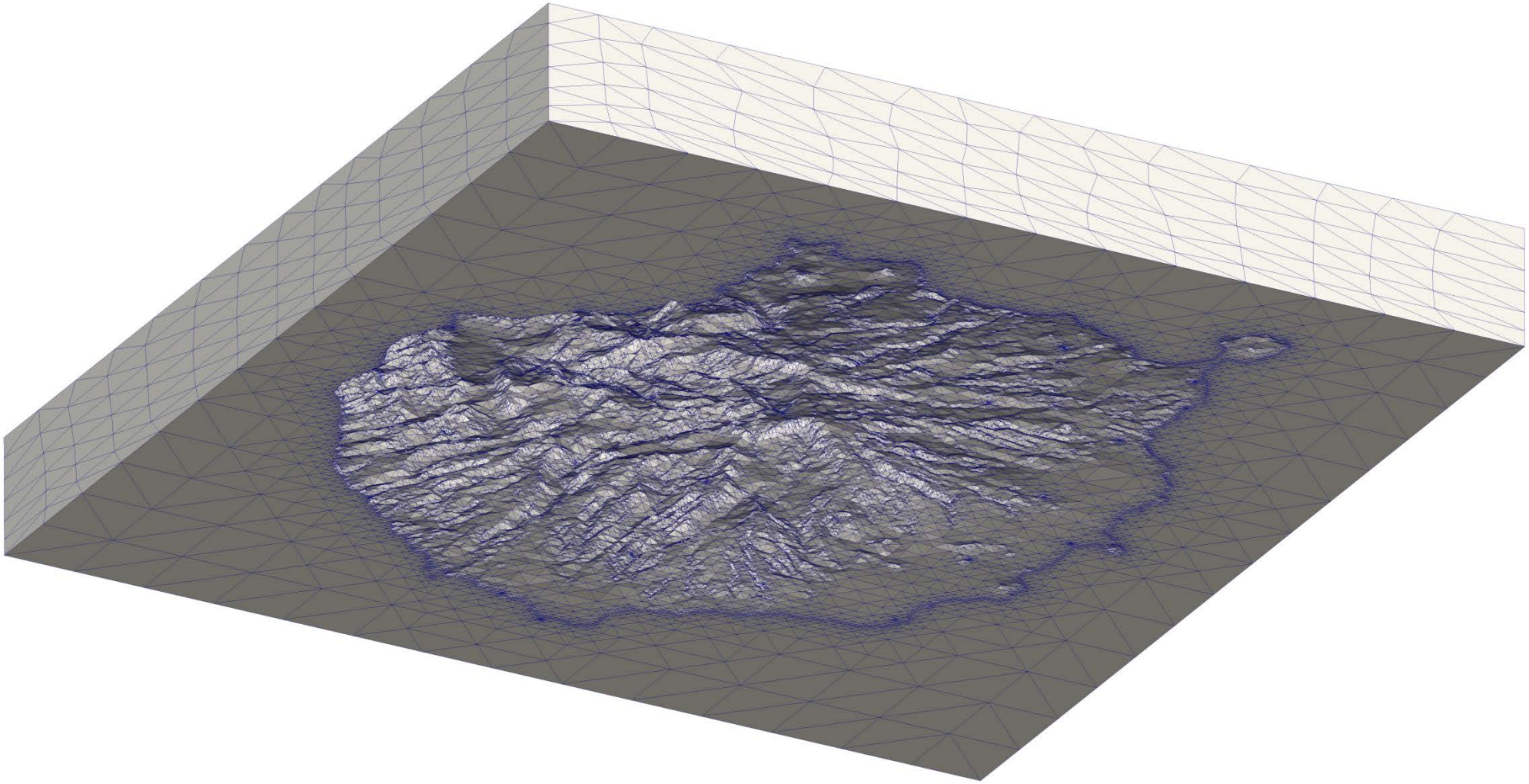
"Discretization and Applications" and "Advanced Numerical Algebra"





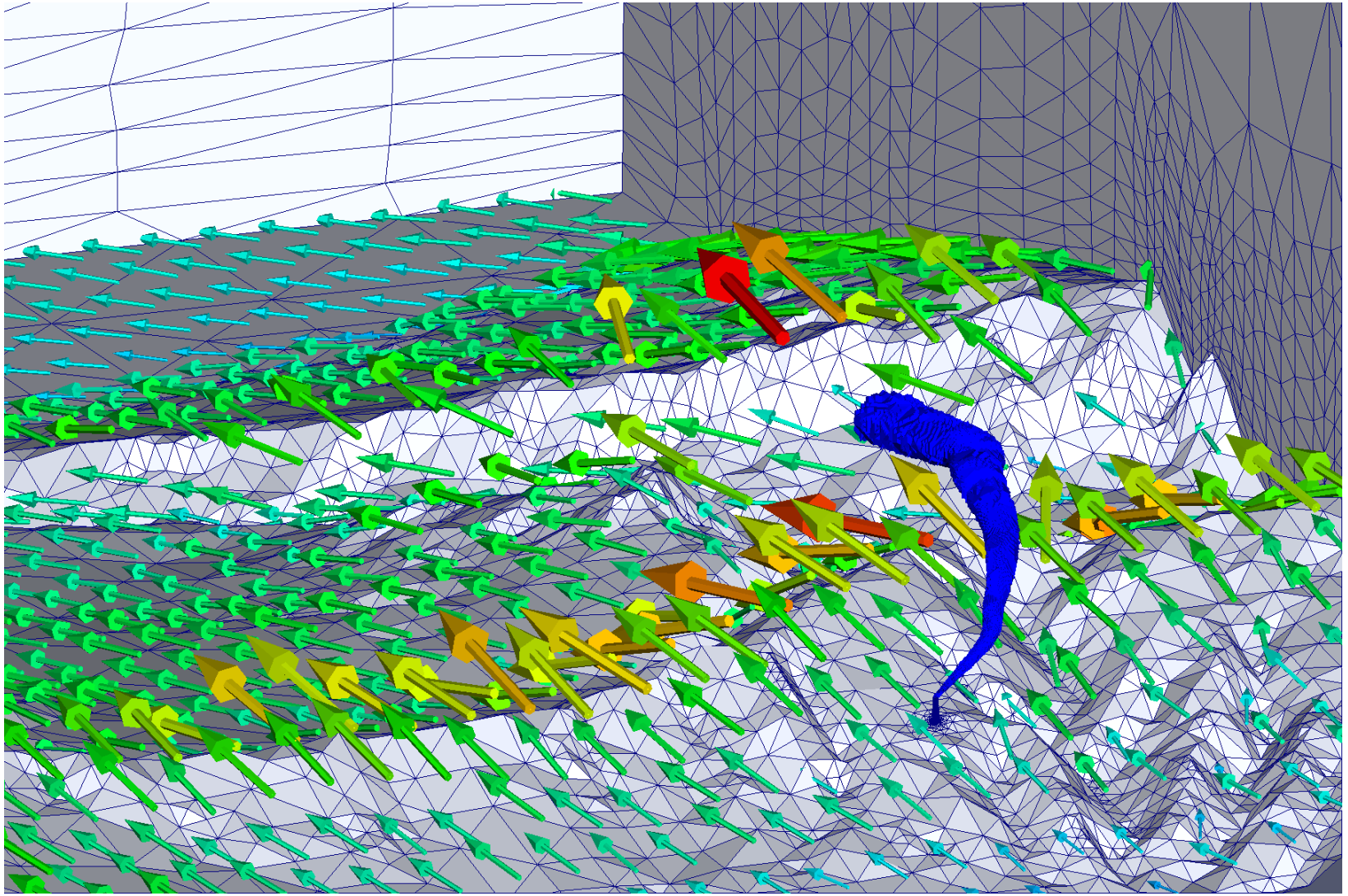
Research Lines

Tetrahedral mesh of Gran Canaria island



Wind Field for Air Quality Simulation

Mesh adaptation to geometry and gaussian pollutant plume



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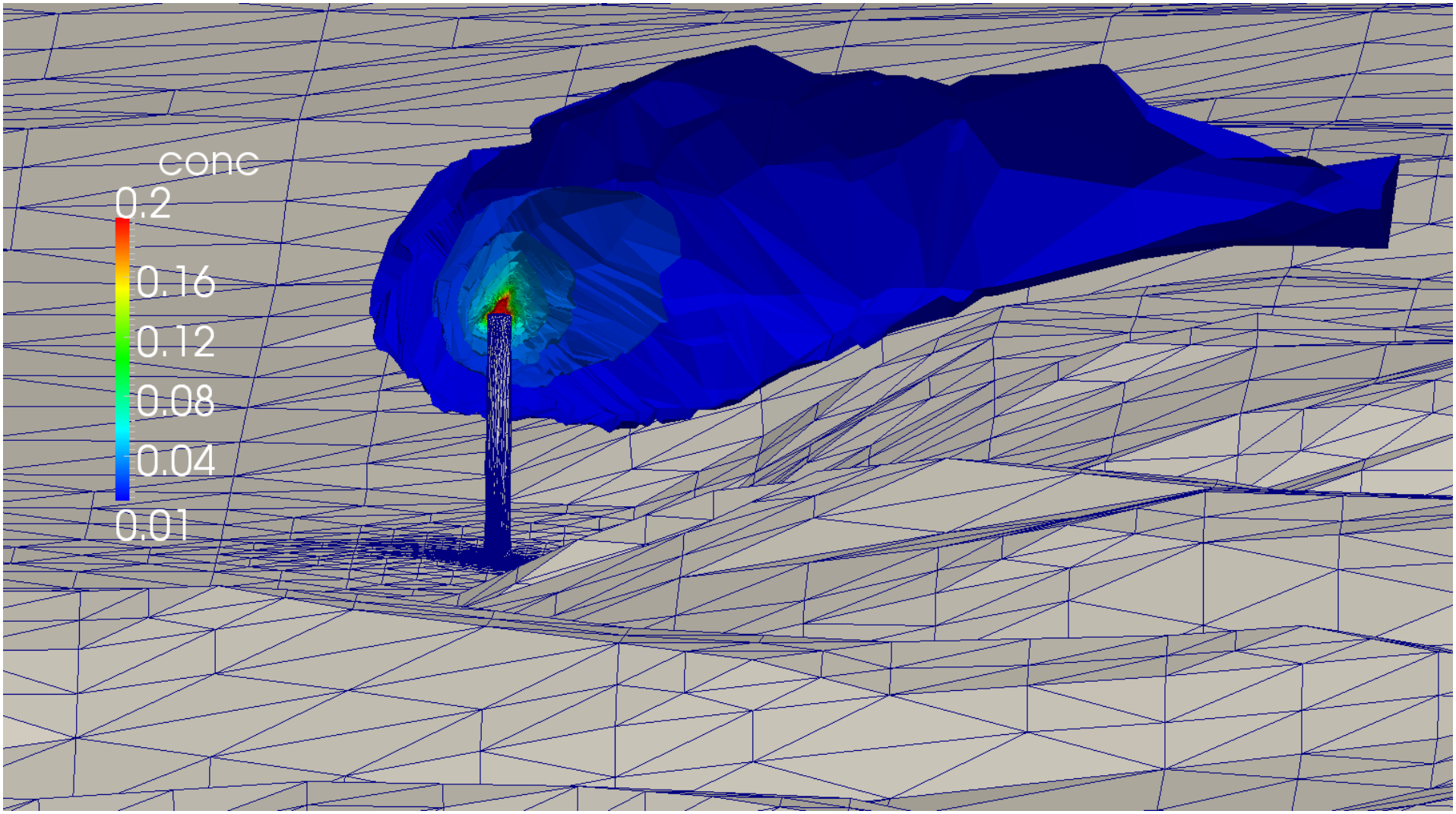

Activity

Mesh generation and systems of equations

Discretization and Applications

Advanced Numerical Algebra

Period 17/05/2012- 28/02/2015
Funding 1.350.000 US$
Numerical simulation of oil fields
Sectoral Fund CONACYT-SENER-HIDROCARBUROS of the Government of Mexico with registration number 163723 with Petrosoft company.
Financed by PEMEX: 5.000.000 US$.

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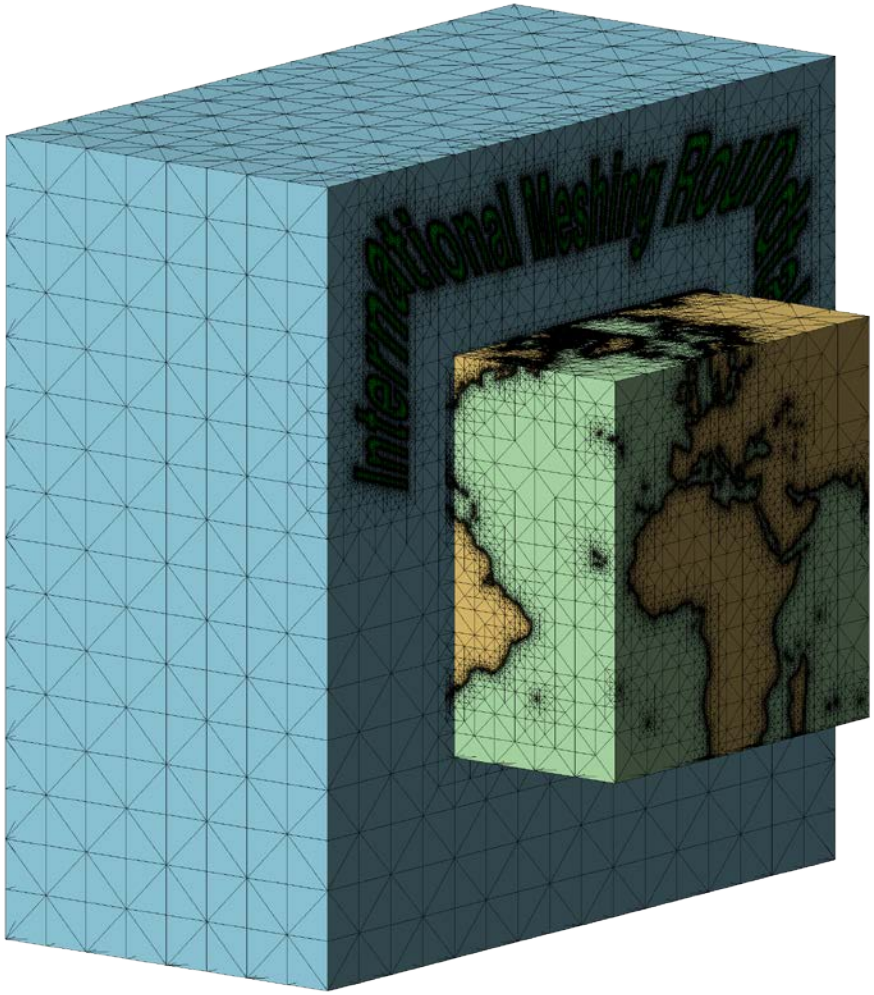
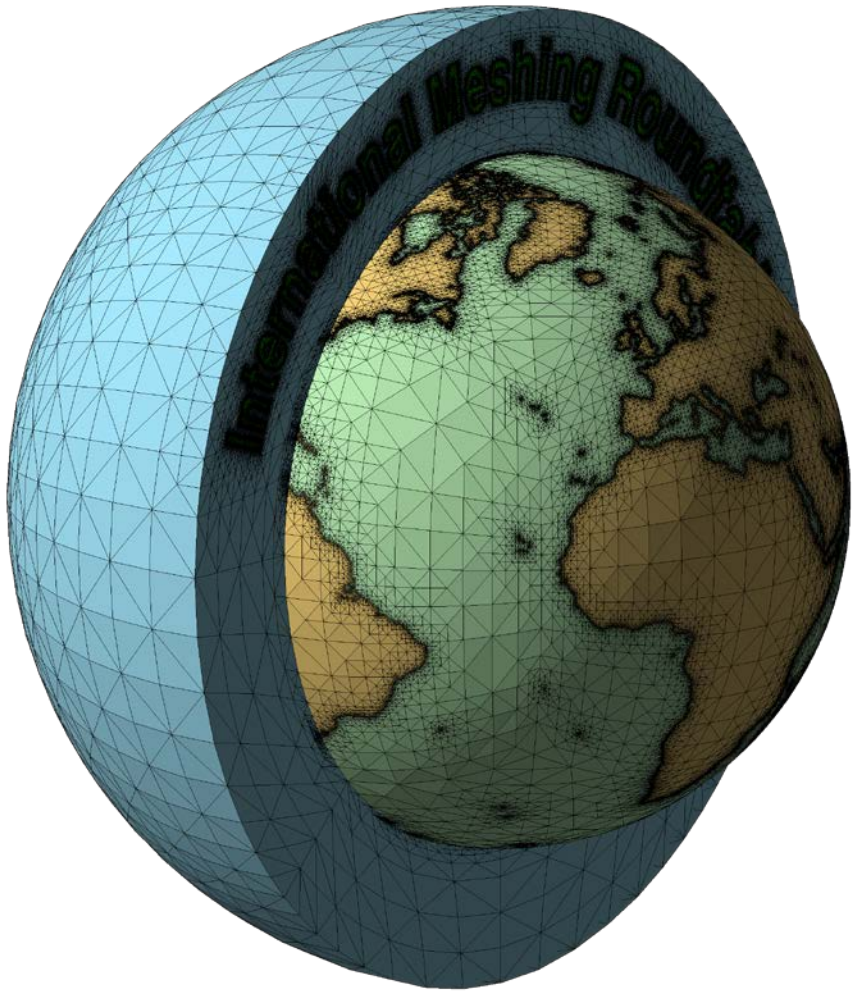
Mesh Generation

Meccano Method

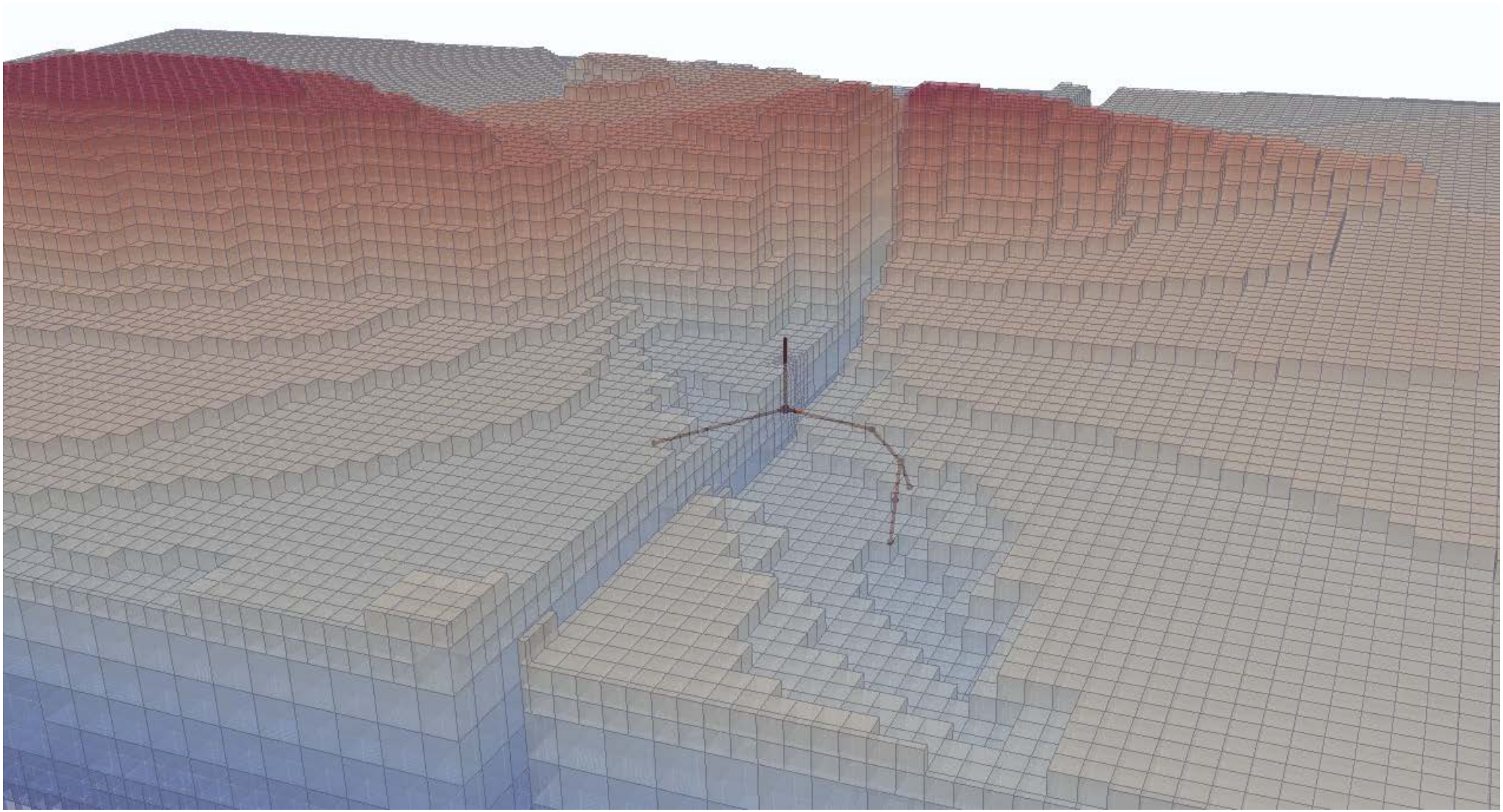




Octree Approximation of an Oil Field

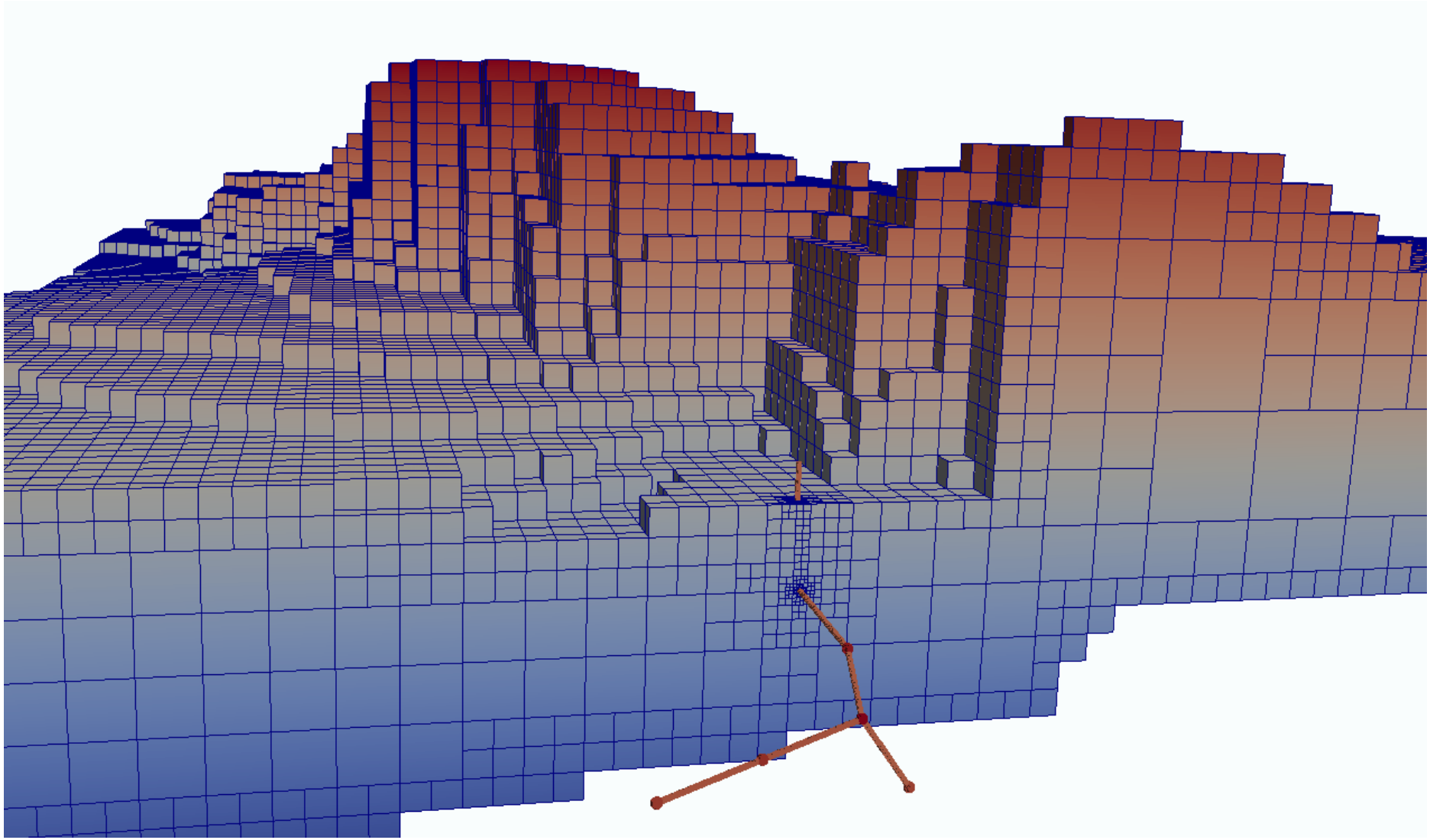
Petrosoft Project (México)

SIANI



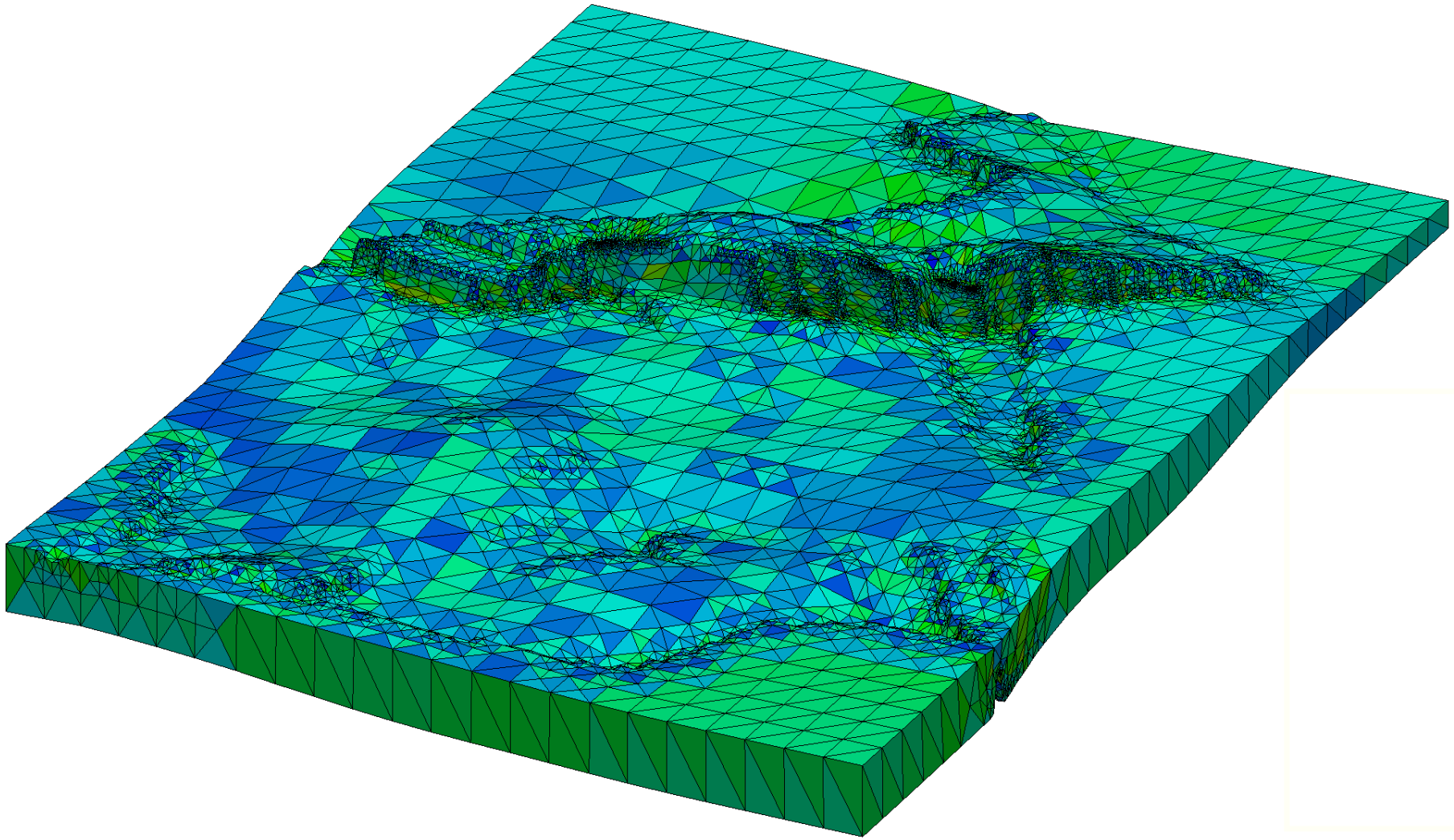
Octree Approximation of an Oil Field

Petrosoft Project (México)



Tetrahedral Approximation of an Oil Field

Petrosoft Project (México)



Activity

Dynamic behaviour of dams, piles and structures

Continuum Mechanics and Structures

MEC/MINECO and FEDER projects

DPI2001-2377- C02-02

BIA2004-03955-C02-02

BIA2007-67612-C02-01

BIA2010-21399-C02-01

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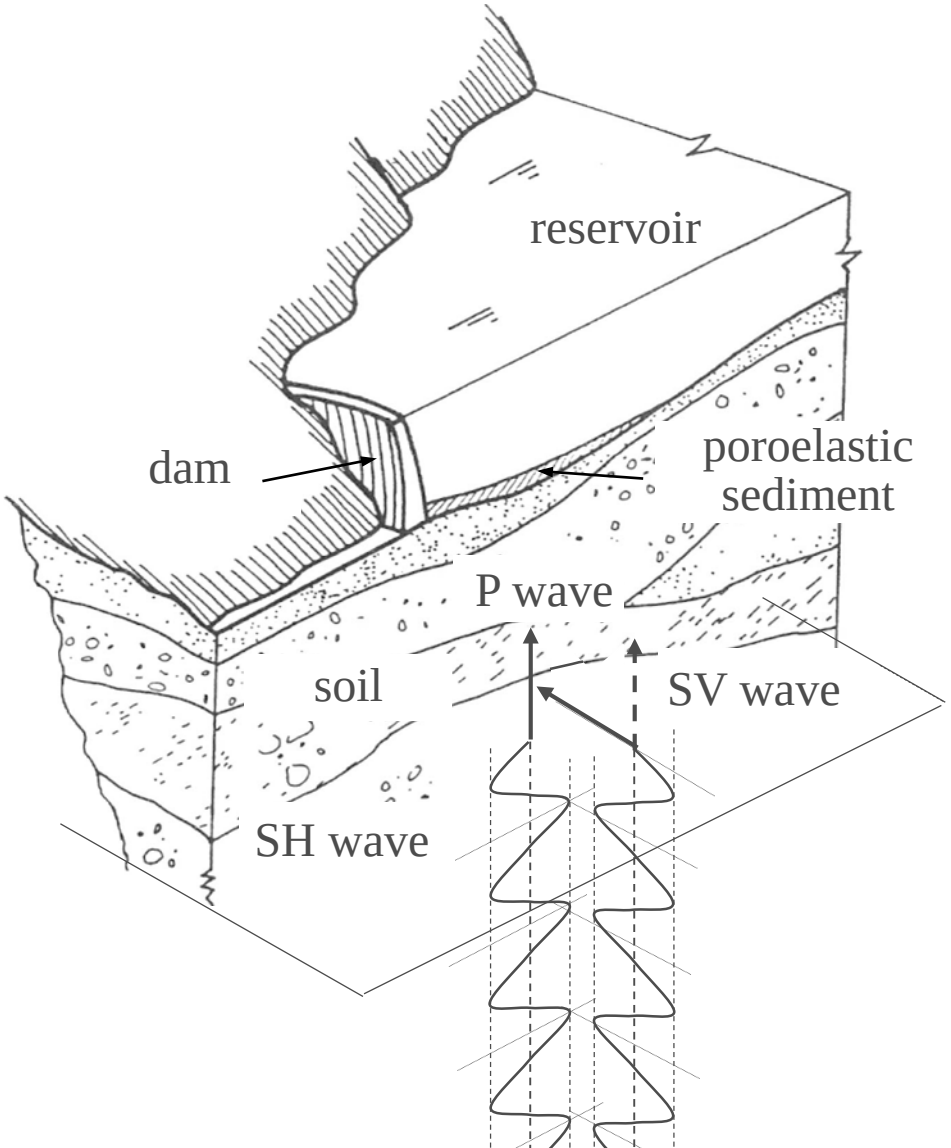
Research Lines

Continuum Mechanics and Structures

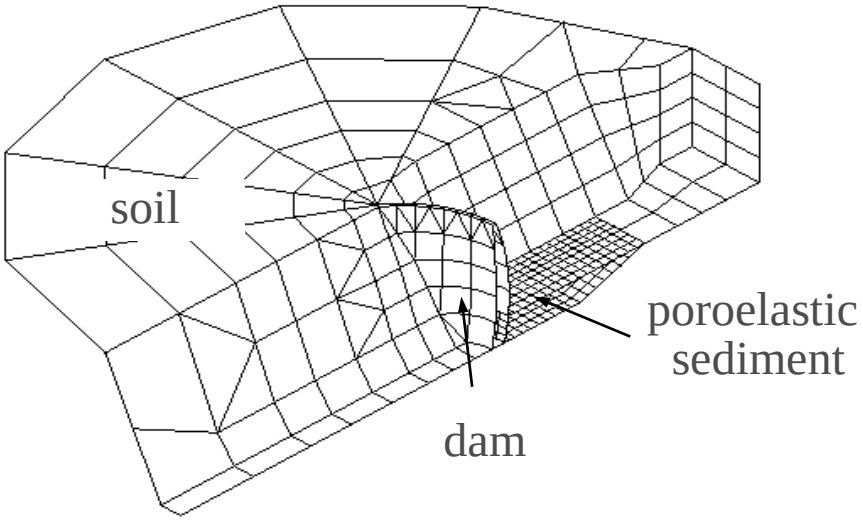
- Numerical modeling of elastodynamic and poroelastodynamic problems
- Soil-structure dynamic interaction problems
- Seismic analysis of structures
- Seismic response of arch dams
- Seismic response of foundations
- Propagation of acoustic waves
- Noise propagation modeling
- Acoustic screens

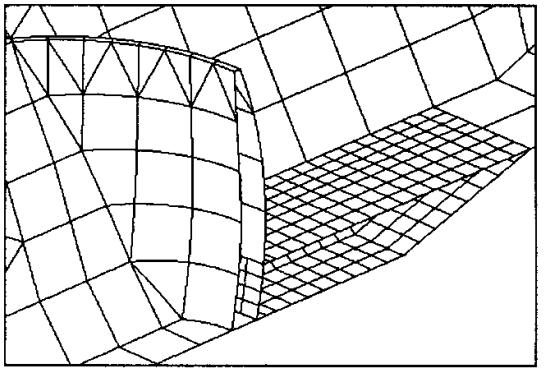
Research Lines

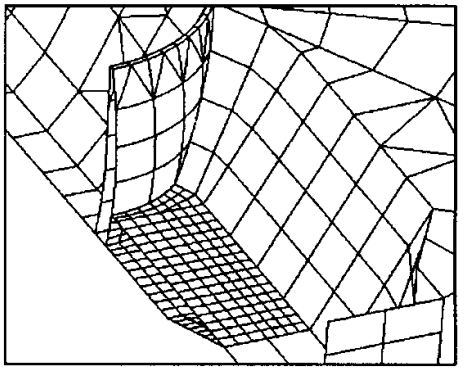
Continuum Mechanics and Structures



reservoir with sediments

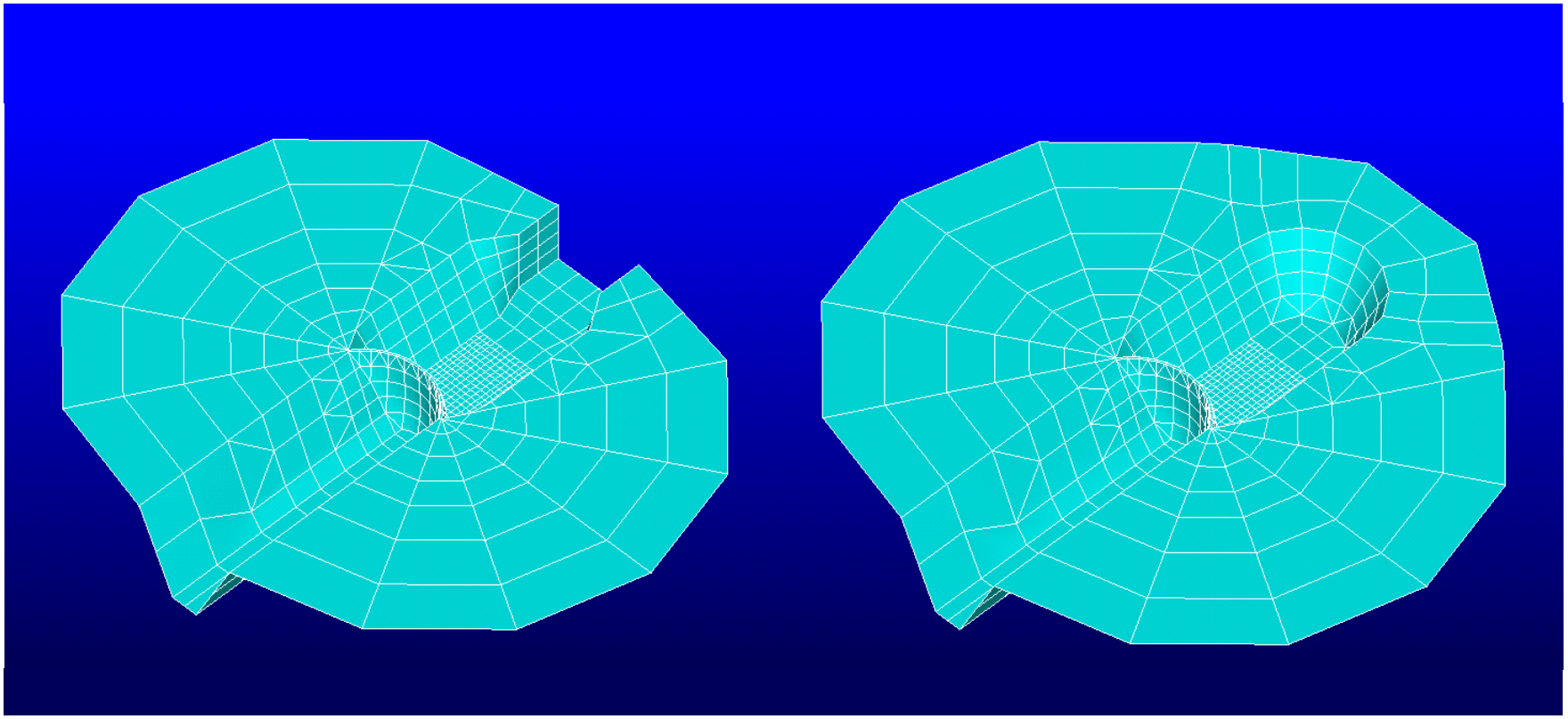






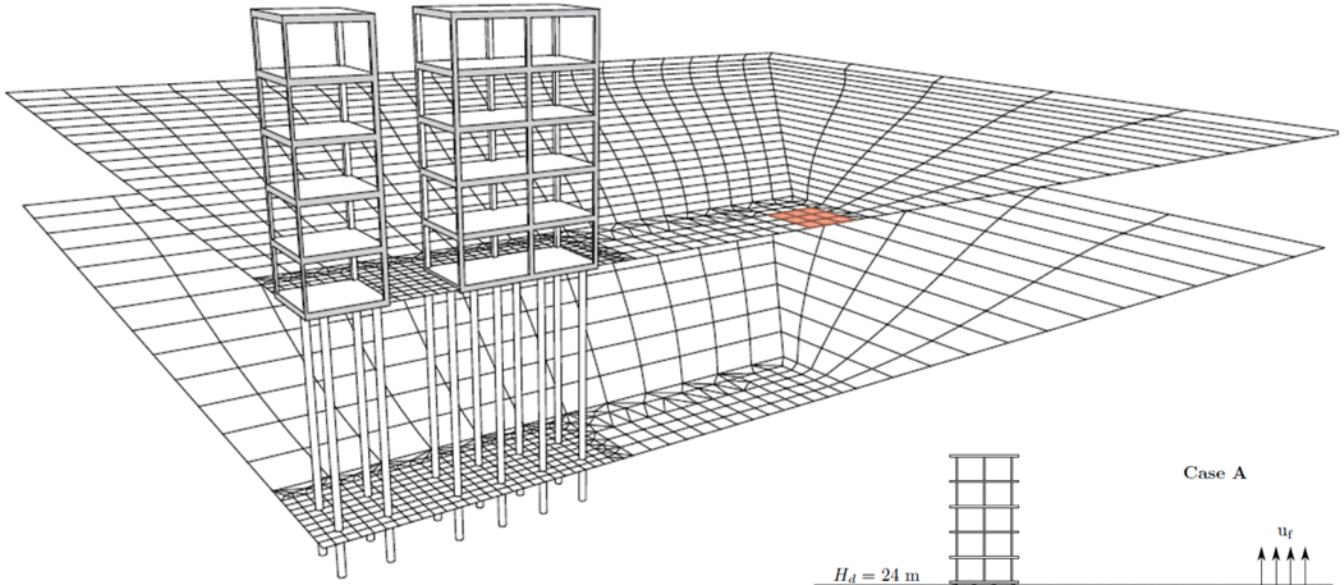
Research Lines

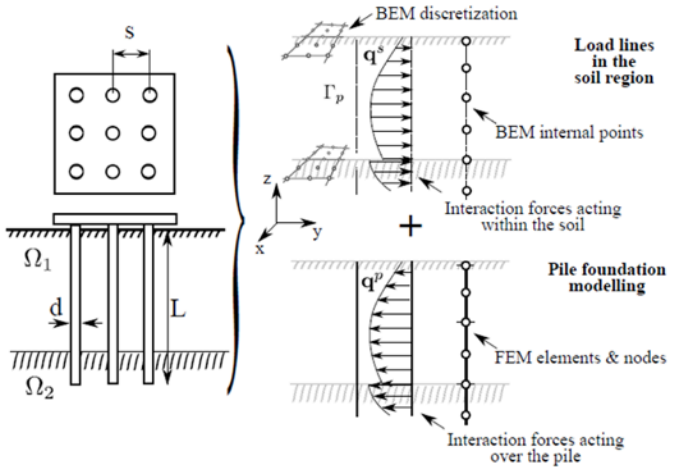
Continuum Mechanics and Structures

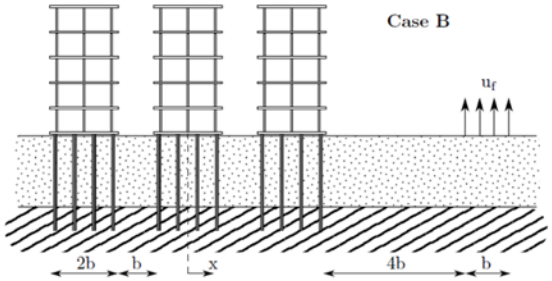


Research Lines

Continuum Mechanics and Structures







Activity

Robotics, marine remote sensing and biometrics

Computational Oceanography and Robotics

MEC/MINECO and FEDER projects
PI 2007/039
TIN2008-06068
PI 2010/0062
MAC 2007-2013

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Research Lines

Computational Oceanography and Robotics

- Robotics
- Route planning for subaquatic gliders
- Remote sensing applications (Marine Meteo NW Africa, Telecan)

Research Lines

Computational Oceanography and Robotics

SIANI

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Challenger Mission

►► I-COOL MISSION BLOGS

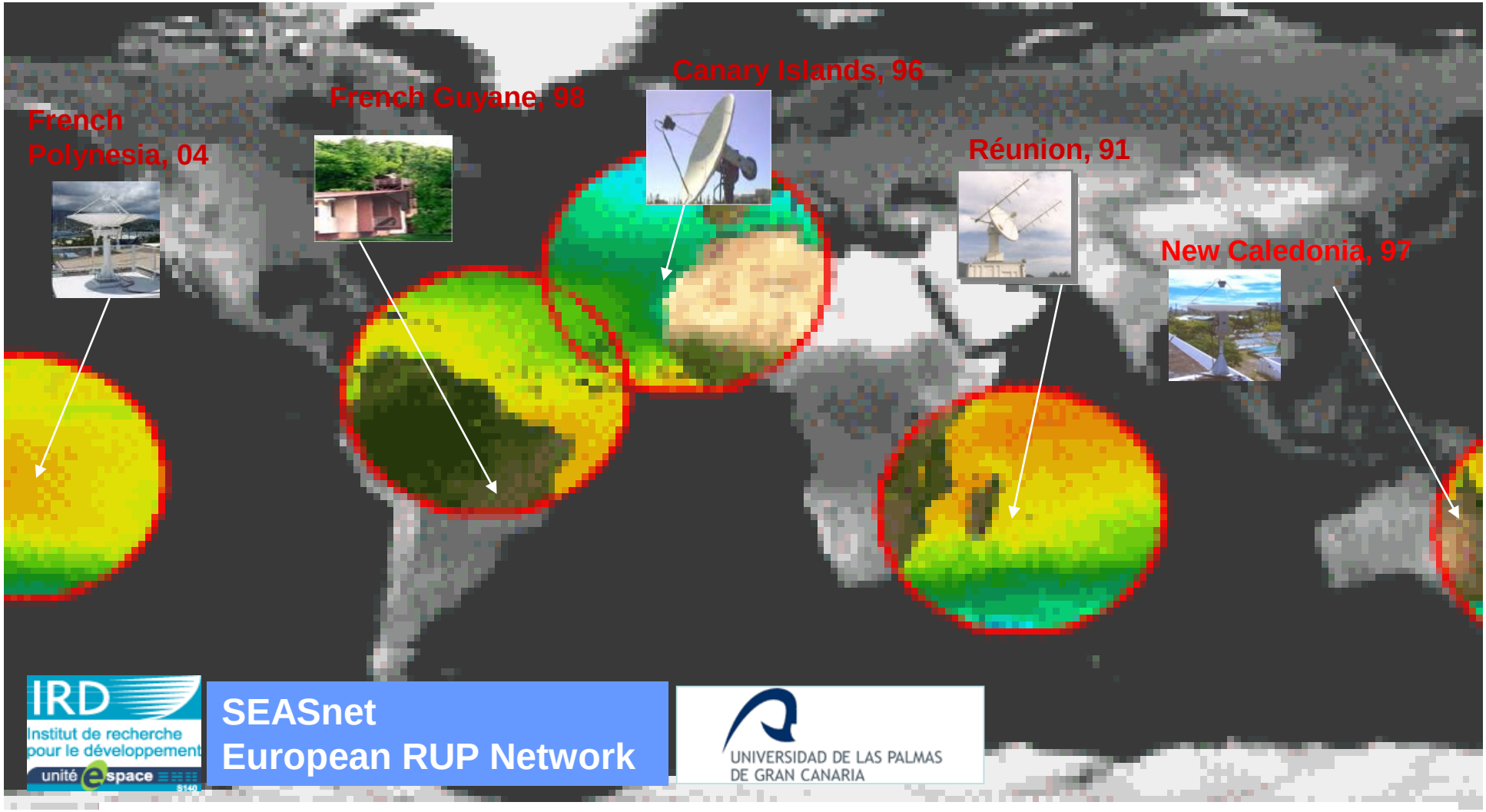
- Australian Adventures 2011
- Axial Seamount Cruise
- Challenger Mission
- Oceanography House
- Undergraduate Operations

► HISTORIC BLOGS

- Across the Pond
- Antarctic Blog
- Atlantic Crossing
- Espresso & Biospace
- Flight to Halifax
- Middle Atlantic Bight
- NORUS
- NURC Med Cruise 09

Research Lines

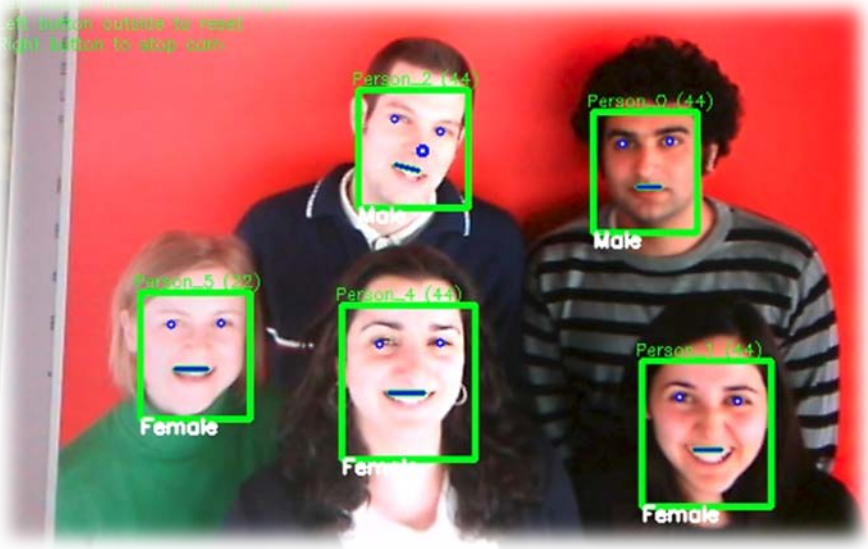
Computational Oceanography and Robotics

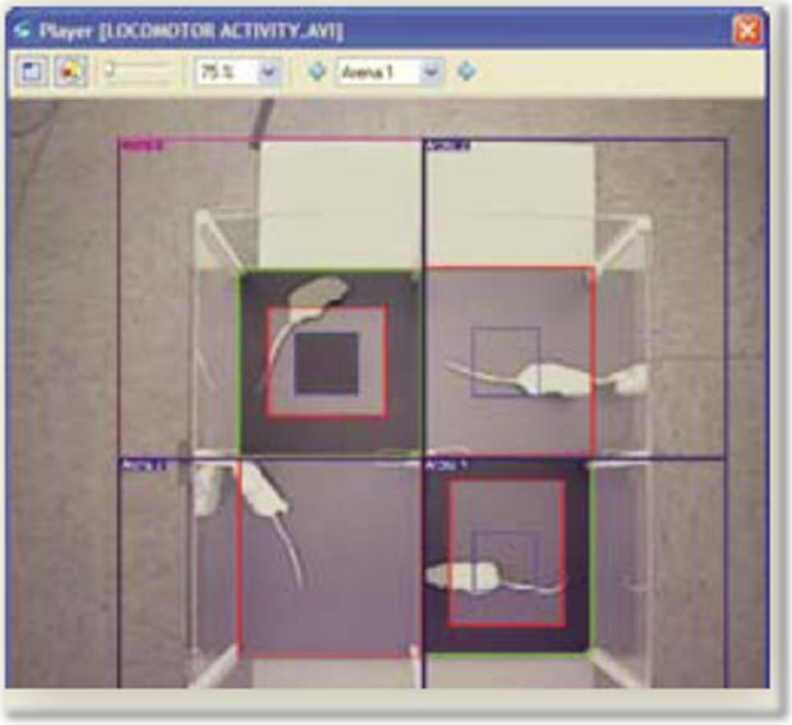


Research Lines

Computational Oceanography and Robotics

- Computer vision and biometrics
- Monitoring and identification of persons and animals in video
- Automatic estimation of gender and age
- Behaviour analysis in video





Activity

Reliability and maintainability

Geo-temporal systems for data processing, analysis and decision-making assistance system

Evolutionary Computation and Applications

CDTI/MICINN/MINECO, FEDER, EUROPEAN projects

BRRT-CT-5034

DPI2001-3570

CENIT-E, *MAR2*

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Research Lines

Evolutionary Computation and Applications

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- Renewable energies
- Risk analysis. Vulnerability. Reliability
- Contingency plans. Action protocols
- Geo-temporal platforms of data acquisition and analysis
- Stereo display and 4D visual monitoring software
- Design of Unmanned Aerial Vehicles (UAVs) for security and emergency applications
- Integration of equipment in UAVs
- Design of action protocols with UAVs

Research Lines

Evolutionary Computation and Applications

September 2009 - March 2013
Collaboration agreement among Iberdrola Ingeniería y Construcción S.A.U., the research organisation CEANI (SIANI-ULPGC) and the entity Fundación Universitaria de Las Palmas CENIT-E project '**Leaders in ocean renewable energies**' OCEAN LÍDER

July 2009 - March 2013
Collaboration agreement among Nuevas Estrategias de Mantenimiento S.L., the research organisation CEANI (SIANI-ULPGC) and the entity Fundación Universitaria de Las Palmas CENIT-E project **'Leaders in ocean renewable energies'** OCEAN LÍDER

Financing entity: CDTI-MICINN; Spanish Government

Research Lines

Evolutionary Computation and Applications

Design, development and operation of a comprehensive crisis management system (SIGE) to face pollution incidents by hydrocarbons affecting the marine environment (Applications in Galicia and the Canaries)

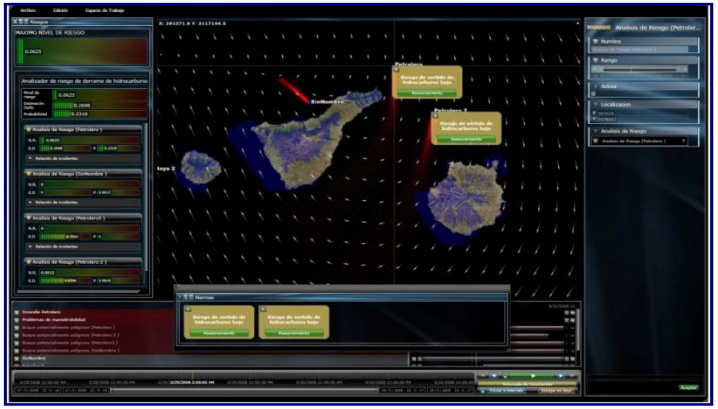
Financing entity: MINECO; Spanish Government

Subprogramme INNPACTO 2011: National public-private cooperation programme for R&D&I projects targeted on products, processes and services with a clear focus to results and based on demand.

Total budget 1,4 M€, 2,5 years (2011-2013)

956 k€ financed

900 k€ of subsidy, loan and/or repayable advance FEDER



INNPACTO Unión Europea FEDER Invertimos en su futuro

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMIA Y COMPETITIVIDAD

Activity

Themodynamics and physicochemical of fluids

Thermal engineering and instrumentation

MEC/MINECO, FEDER, EUROPEAN projects

GR88-0077
PB89-0508
JOU2-CT92-0060
PB92-0559
JOU3-CT95-0009
PB95-0025
PPQ2000-0235
PPQ2003-04404
CTQ2005-24273
CTQ2006-12067
CTQ2009-12482
CTQ2012-37114

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Research Lines

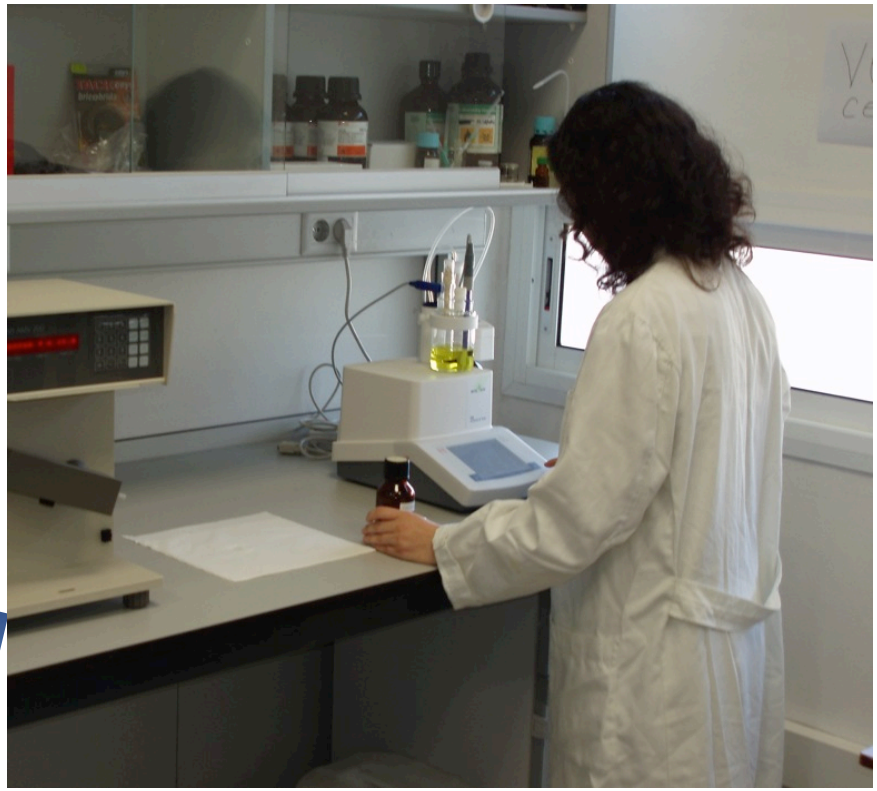
Thermal Engineering and Instrumentation

- **Experimentation on the physicochemical behaviour of fluid substances**
  - New models for experimental data processing
  - Mathematical modeling of fluids (pure or mixed) behaviour
  - Advanced studies on the behaviour and the structure of the fluid matter
  - Correlations using advanced algorithms

- **Instrumentation**
  - Improvement of the available instrumentation, automation of experimental systems to operate continuously
  - New designs of equipments
  - Simulation of experimental processes

Research Lines

Thermal Engineering and Instrumentation



Activity

Integration of renewable energies

Models for prediction and management of power demand in electrical grids

Quality, Efficiency and Sustainability

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Research Lines

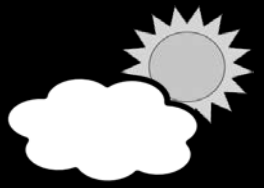
Quality, Efficiency and Sustainability

Integration of renewable energies in the electrical generation mix

Demand Side Management (DSM)

Research Lines

Quality, Efficiency and Sustainability

	Management	Prediction
Production		
Demand		

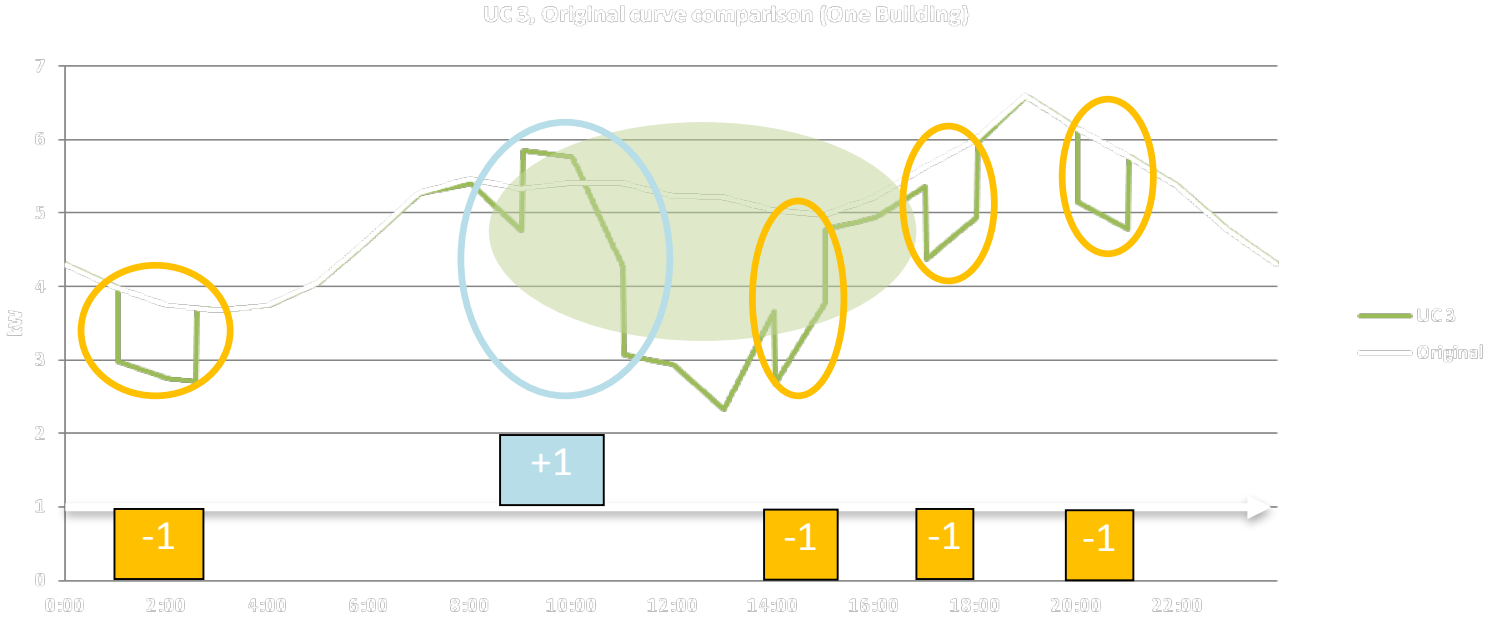
TAFAT

Experimentation Laboratory for testing and analyzing research procedures

Millener

Modeling and simulation of the Reunion Island in order to analyse the impact on the grid of the introduction of photovoltaic panels and batteries in housing.

Project contracted by EDF R&D (participating EDF R&D, EDF SEI, Edelia, Schneider, BPLG, DeltaDore, Tenesol, Saft) 30,2 Meuros (ADEME finances 7,2 Meuros)



Postgraduate Programs

Official Research Master Degrees and Doctorate Program

Video of the University Institute SIANI

Three-dimensional simulation of wind fields and air pollution over complex terrain

A. Oliver[(1)], E. Rodríguez[(1)], J. Ramírez[(1)], J.I. López[(1)], M. Brovka[(1)], J.M. Escobar[(1)], J.M. Cascón[(2)], F. Díaz[(1)], G.V. Socorro[(1)], G. Montero[(1)] and R. Montenegro[(1)*]

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

[(2)] Department of Economics and History of Economics, University of Salamanca, Spain

CEID Annual Seminar 2014, LUT, Lappeenranta University of Technology,

27th May, 2014, Lappeenranta, Finland

MINECO y FEDER Project: CGL2011-29396-C03-00

CONACYT-SENER Project, Fondo Sectorial, contract: 163723

http://www.dca.iusiani.ulpgc.es/proyecto2012-2014

Avances en Simulación de Campos de Viento y Radiación Solar

SIANI INSTITUTO UNIVERSITARIO INGENIERIA COMPUTACIONAL

GOBIERNO DE ESPAÑA · MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

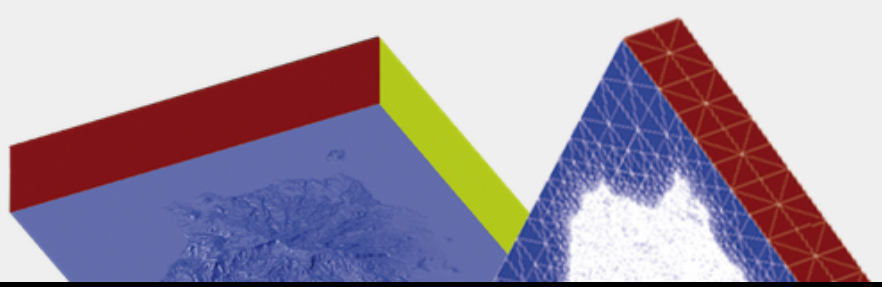
FEDER

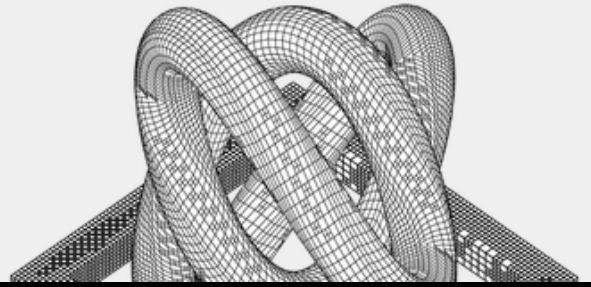
ULPGC

Ministerio de Economía y Competitividad y FEDER
Referencia: CGL2011-29396-C03-01
Plazo de ejecución: 01/01/2012 - 31/12/2014

Descripción del proyecto

Este Subproyecto de Investigación de la Universidad de Las Palmas de Gran Canaria, titulado "Avances en Simulación de Campos de Viento y Radiación Solar", con referencia CGL2011-29396-C03-01, se enmarca dentro del Proyecto Coordinado "Métodos Numéricos Avanzados para Gestión Medioambiental", con referencia CGL2011-29396-C03-00, financiado por el Ministerio de Economía y Competitividad y FEDER a través de la convocatoria de proyectos de investigación, subprograma de Proyectos de Investigación Fundamental no Orientada, dentro del Programa Nacional de Proyectos de Investigación Fundamental, VI Plan Nacional de Investigación Científica, Desarrollo e Innovación Tecnológica 2008-2011.





http://www.dca.iusiani.ulpgc.es/proyecto2012-2014

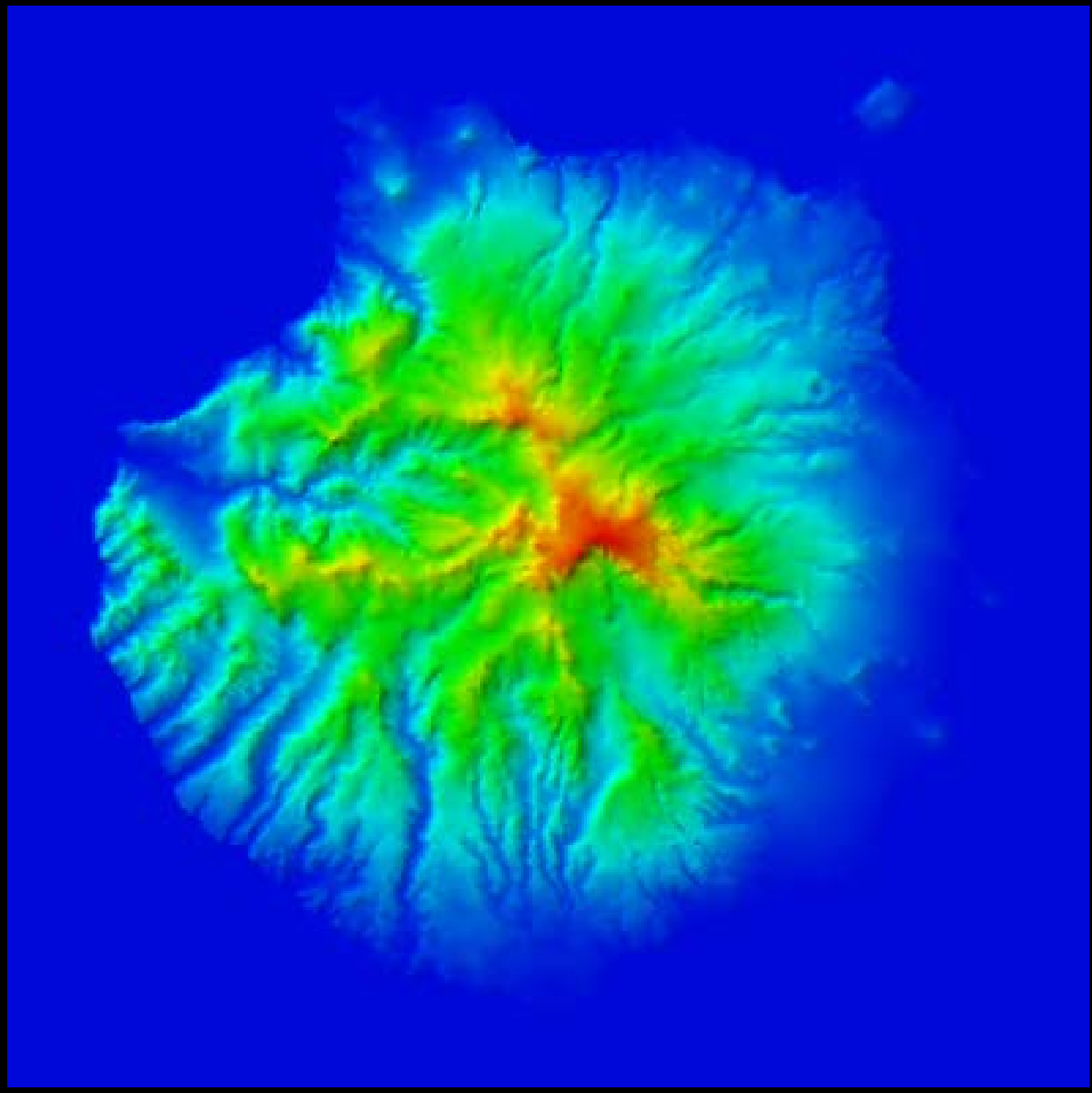
Contents

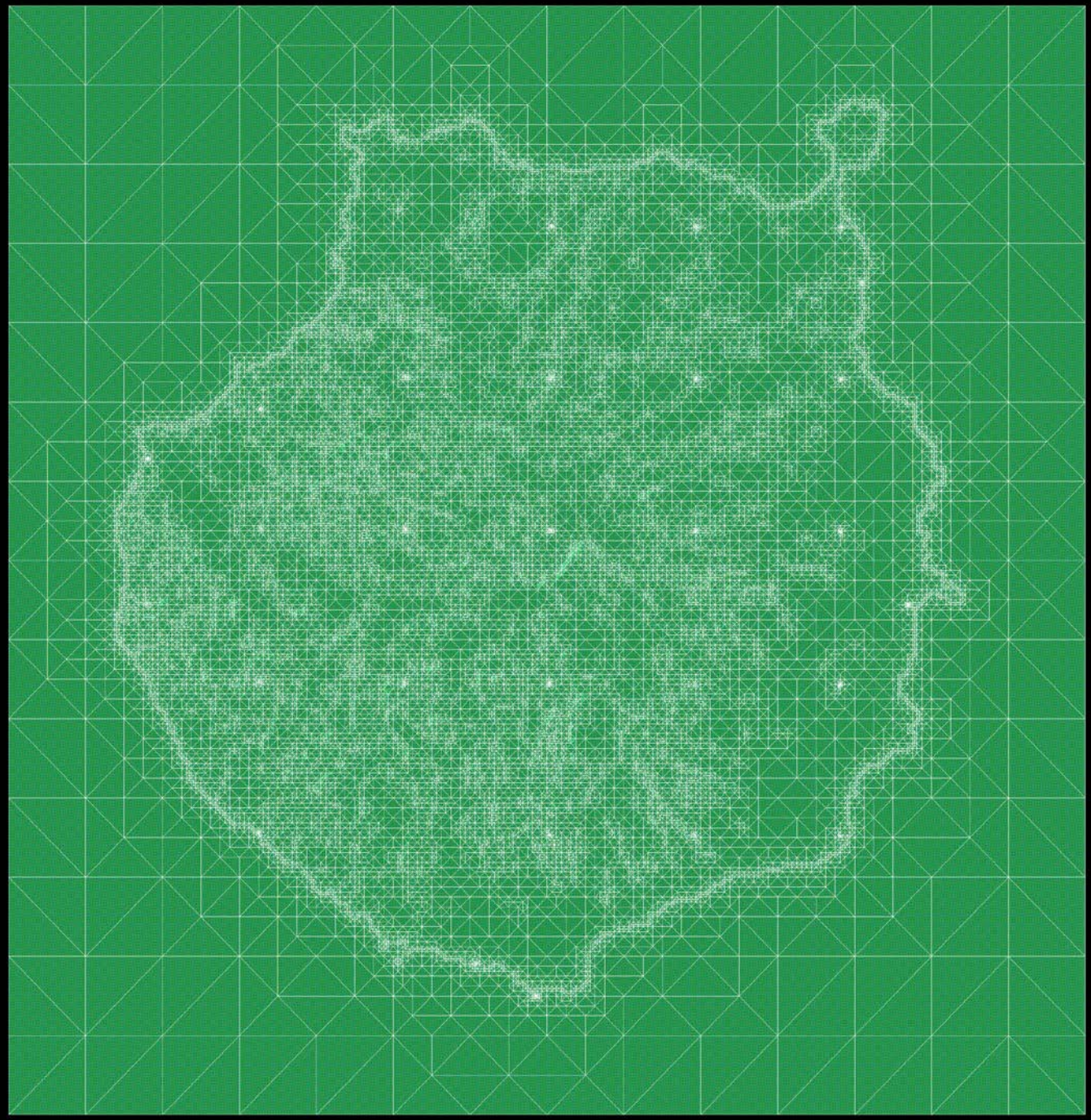
Wind forecasting over complex terrain

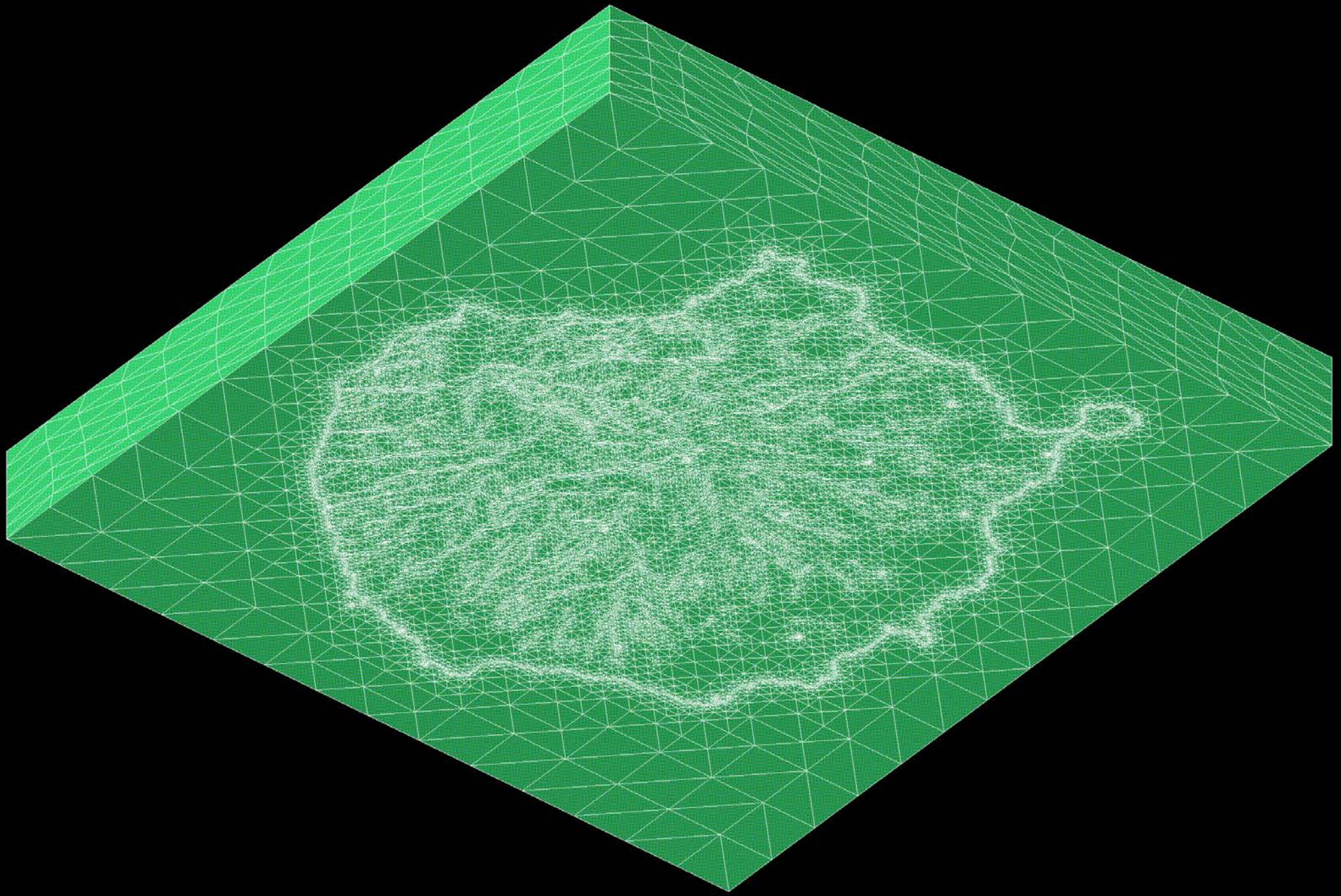
SIANI

- **Motivation, Objective and Methodology**
- **The Adaptive Tetrahedral Mesh (Meccano Method)**
- **The Mass Consistent Wind Field Model**
- **Results**
- **Comments**


Las Palmas de Gran Canaria

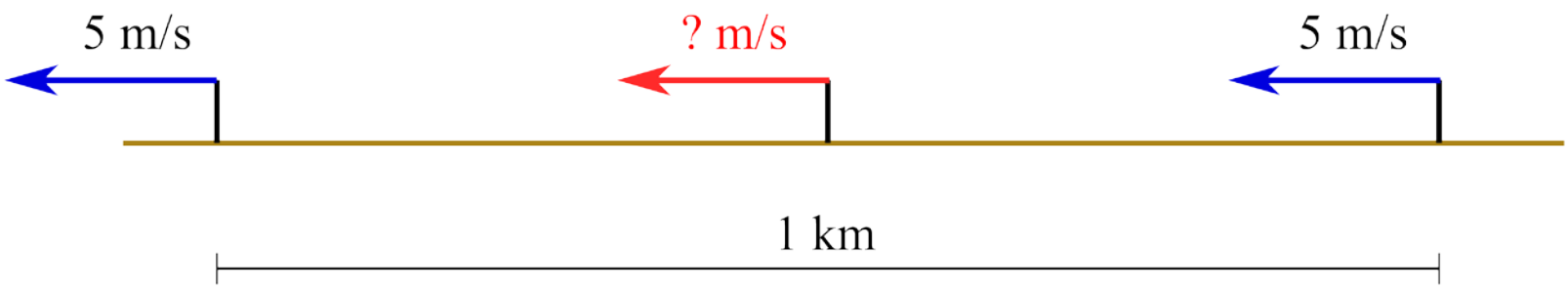






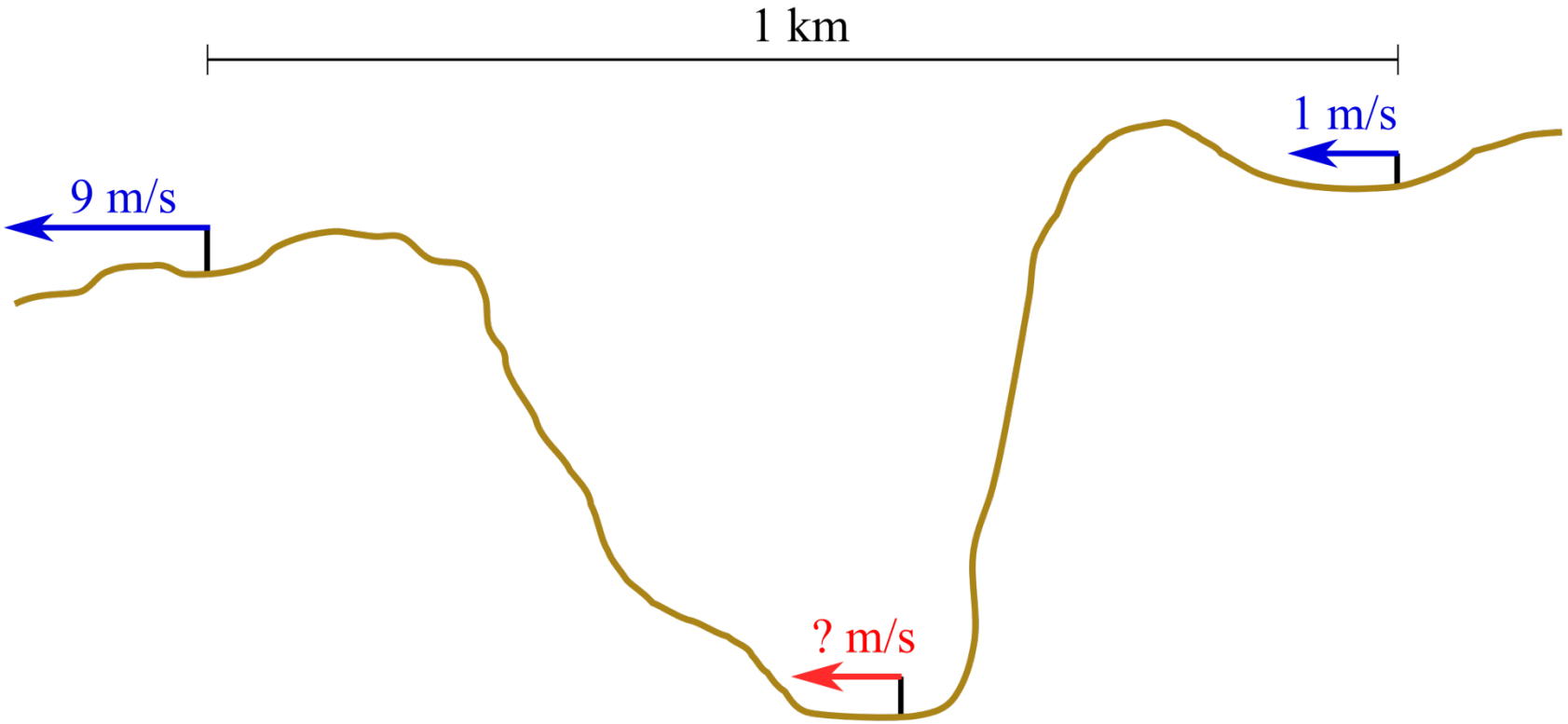
Wind Field Simulation over Complex Terrain

Motivation



Wind Field Simulation over Complex Terrain

Motivation



Wind Field Forecasting over Complex Terrain

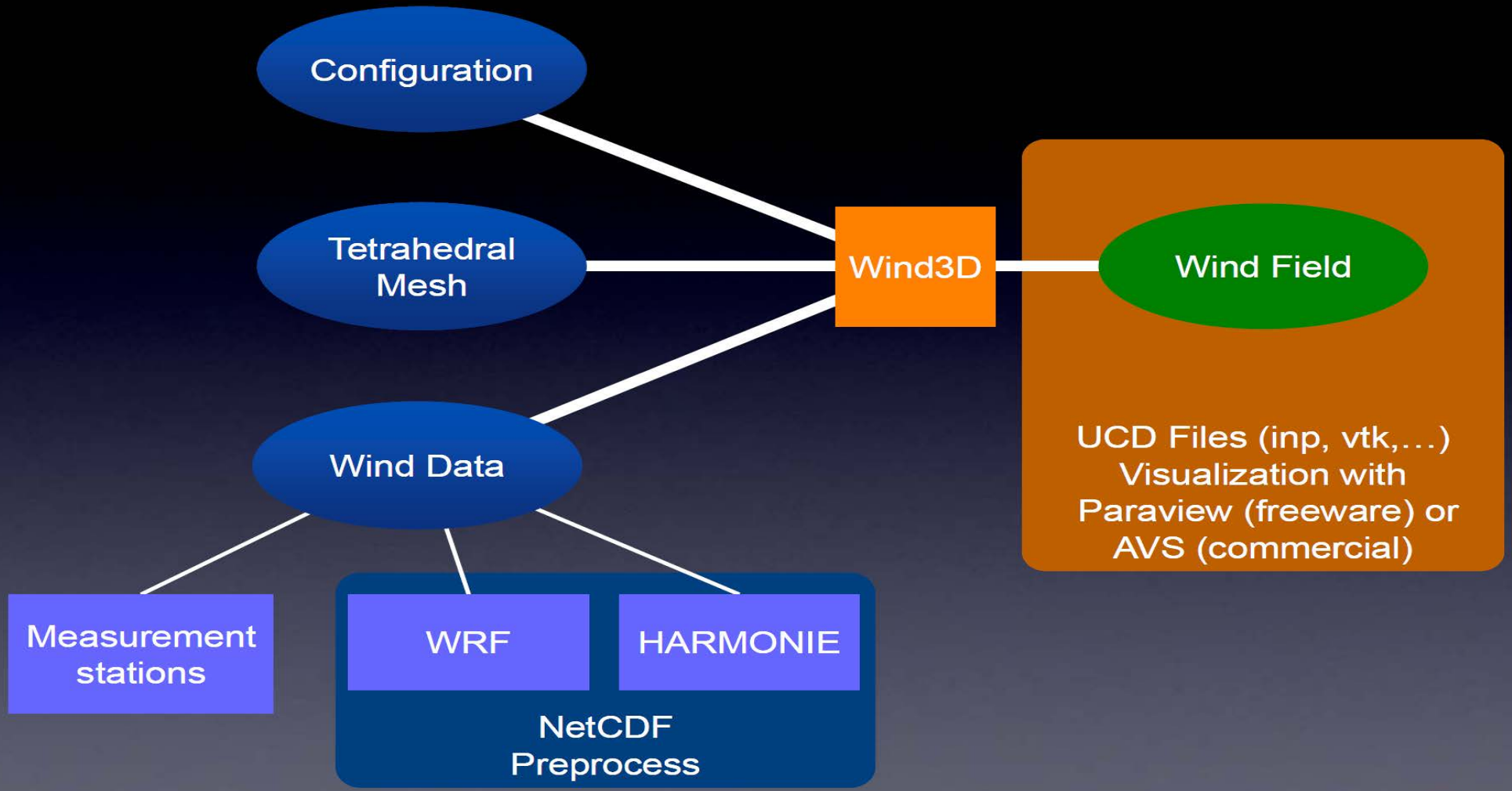
Objective and Methodology

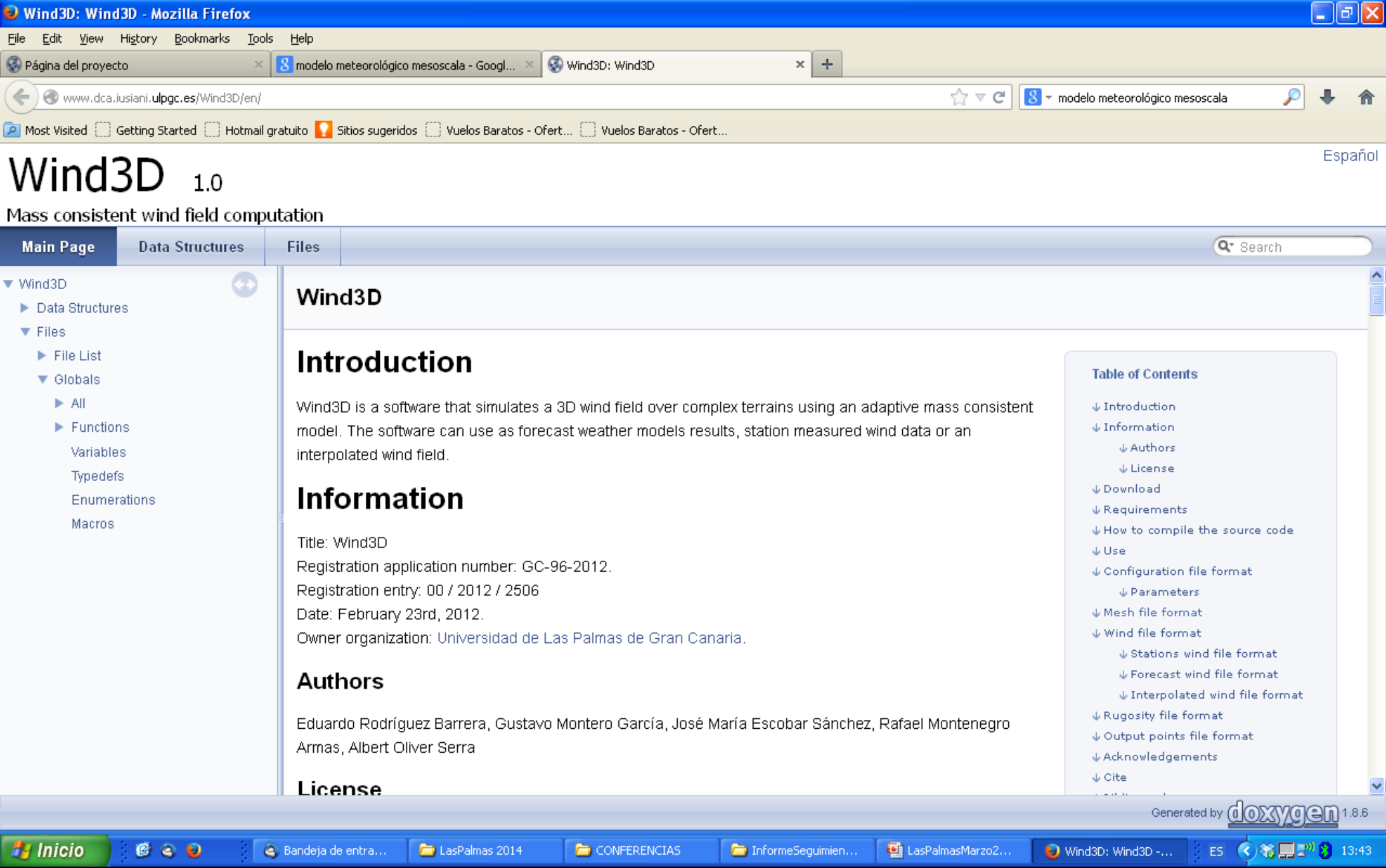
- Objective:
  - Construct a 3-D adaptive finite element mass consistent model for improving local wind forecasting
- Methodology:
  - Wind field forecasting by using a mesoscale meteorological model, MM5, WRF, HIRLAM, HARMONIE,… (resolution of kilometers)
  - Interpolation of these results in the real domain (adaptive tetrahedral mesh). Horizontal and vertical interpolation from wind data (it can be experimental or forecasted data)
  - Wind field adjusting to the interpolated field by using the mass consistent model (resolution of meters)

Wind Field Forecasting over Complex Terrain

Wind3D Code (freely-available)

http://www.dca.iusiani.ulpgc.es/Wind3D/



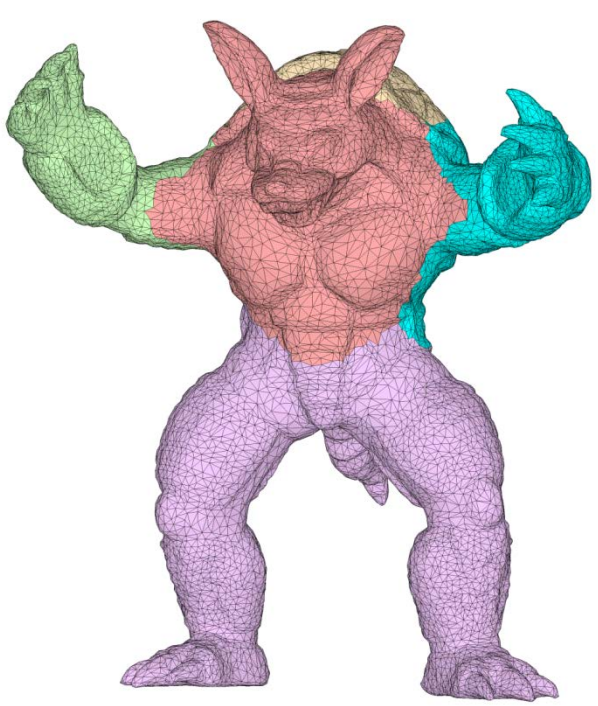


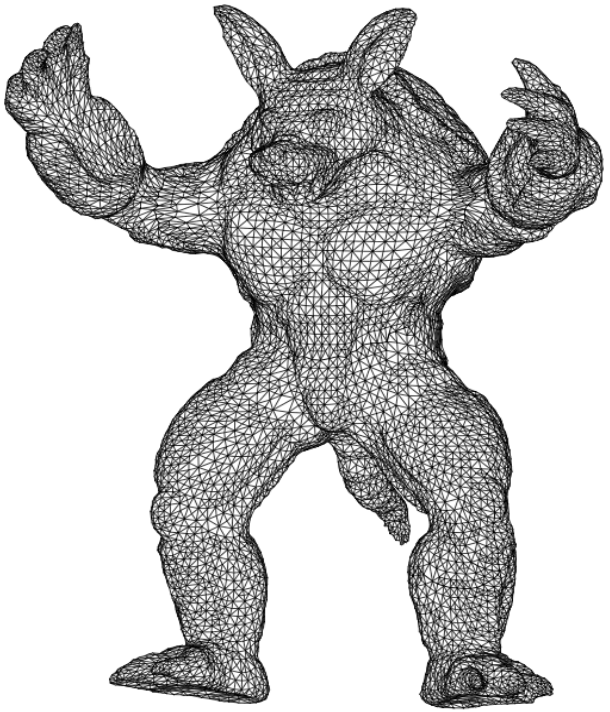
http://www.dca.iusiani.ulpgc.es/Wind3D/

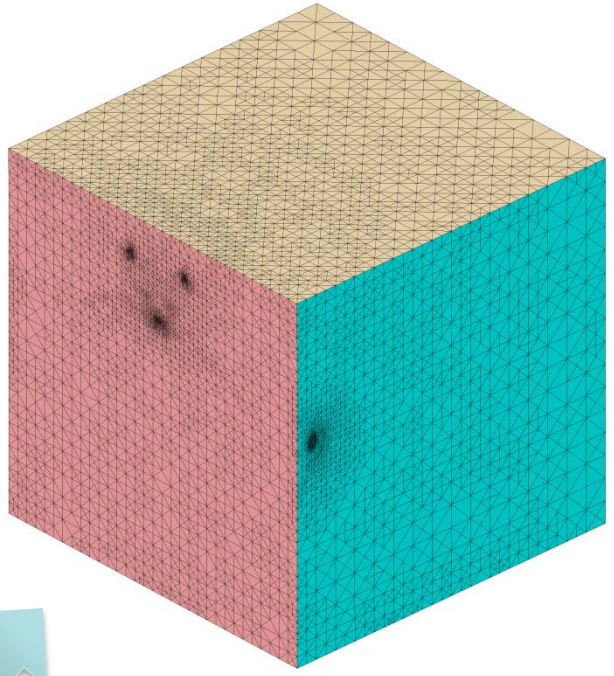
The Adaptive Mesh

Meccano Method for Complex Solids

Simultaneous mesh generation and volumetric parameterization



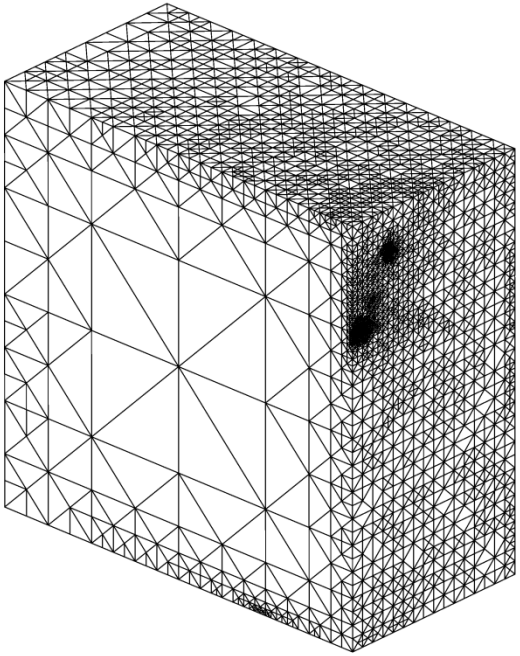




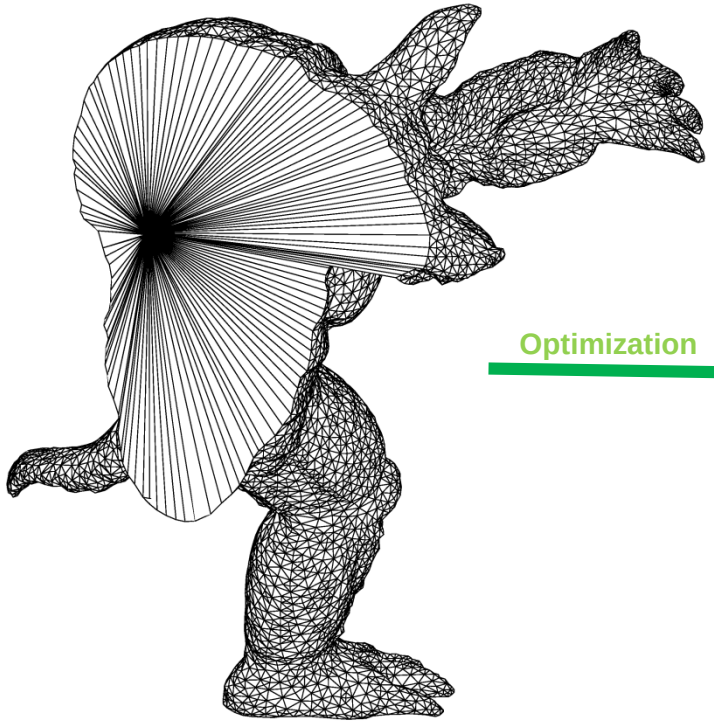
- Parameterization
- Refinement
- Untangling & Smoothing

Meccano Method for Complex Solids

Key of the method: SUS of tetrahedral meshes

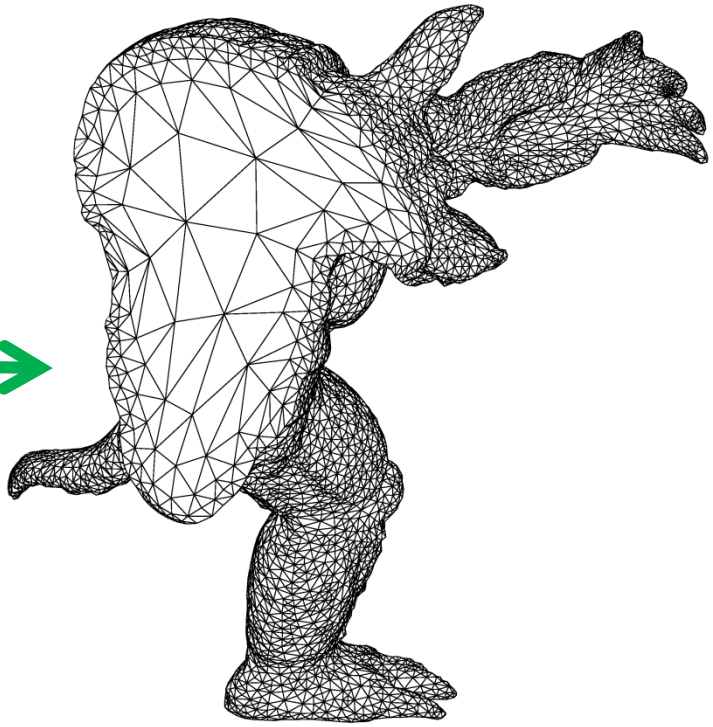


Parameter space
(meccano mesh)



Physical space
(tangled mesh)

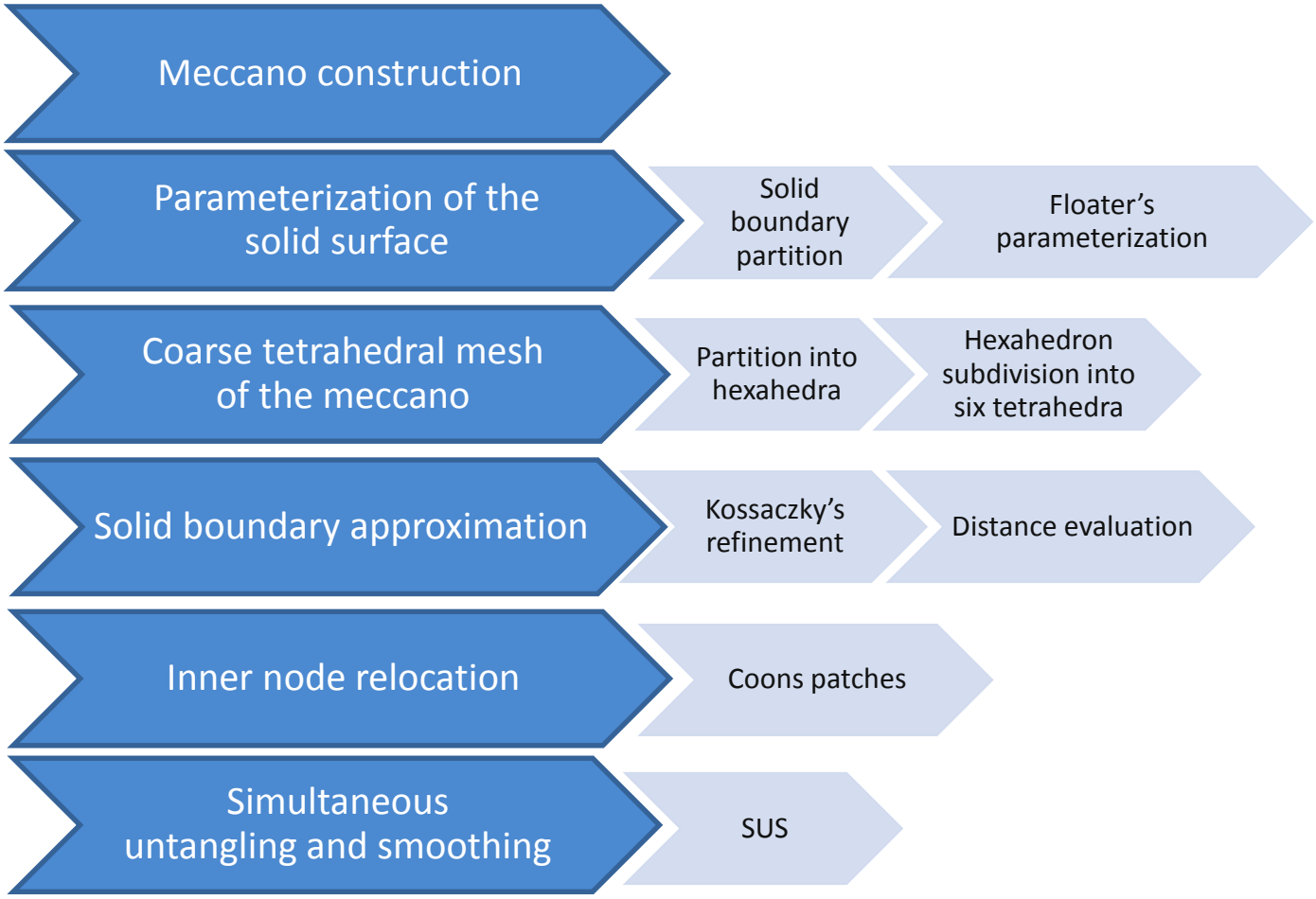
Optimization



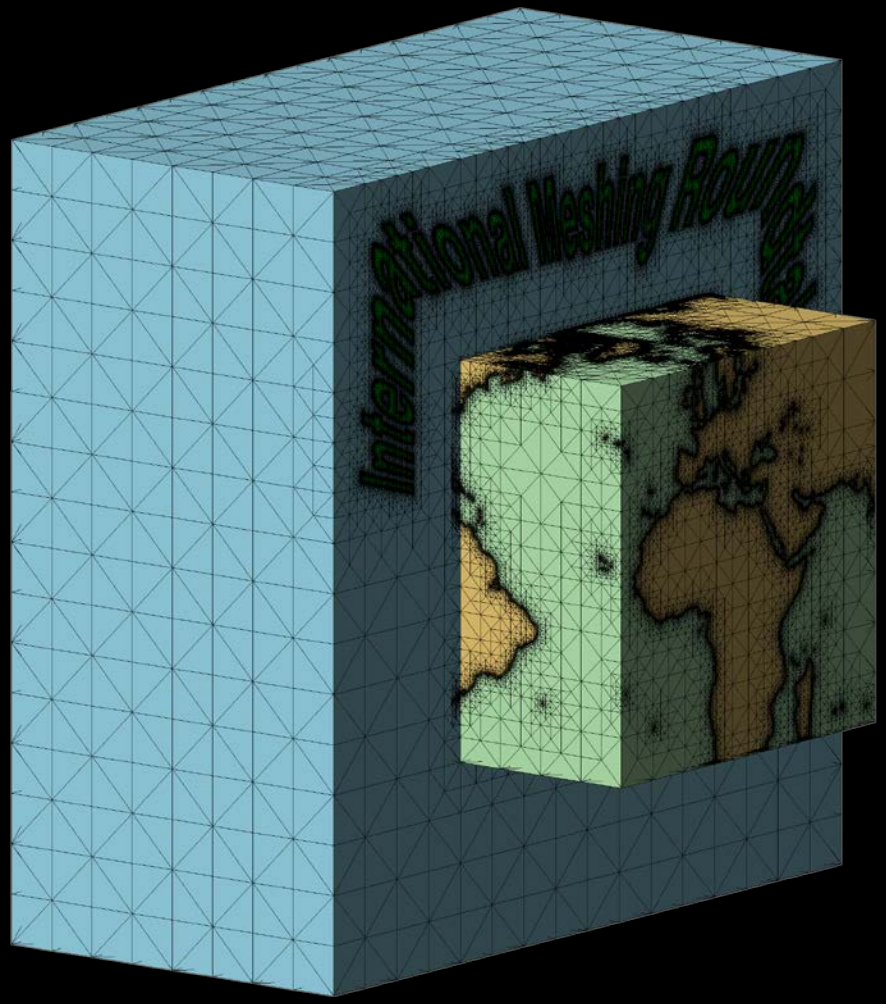
Physical space
(optimized mesh)

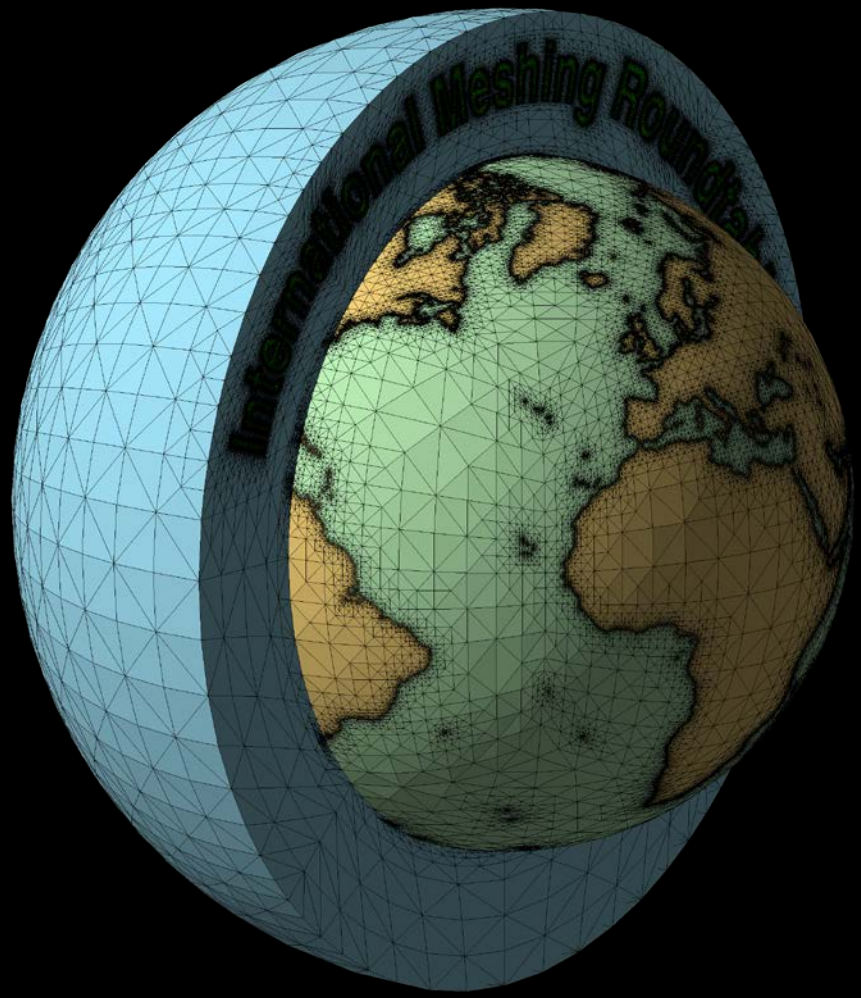
Meccano Method for Complex Solids

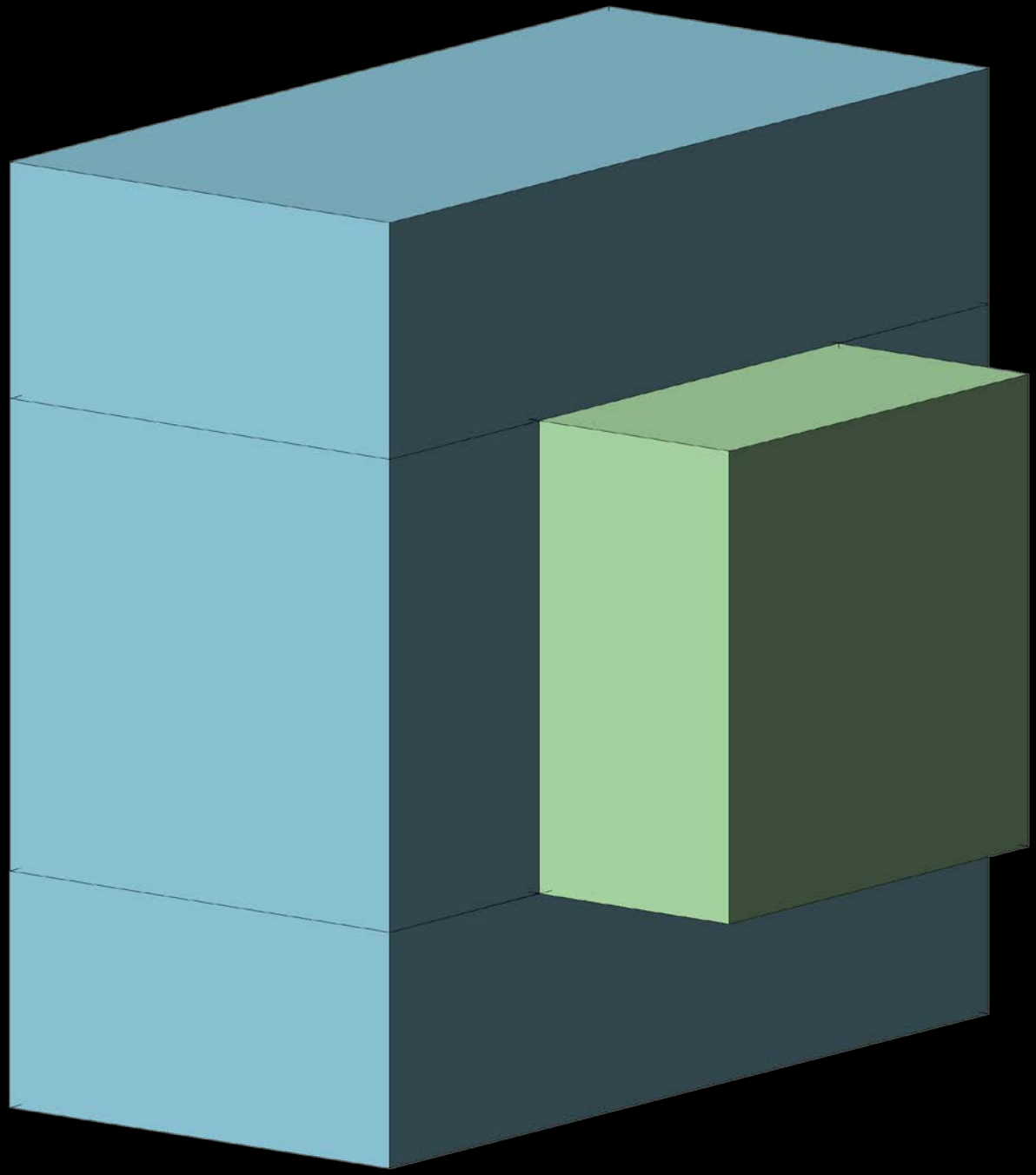
Algorithm steps

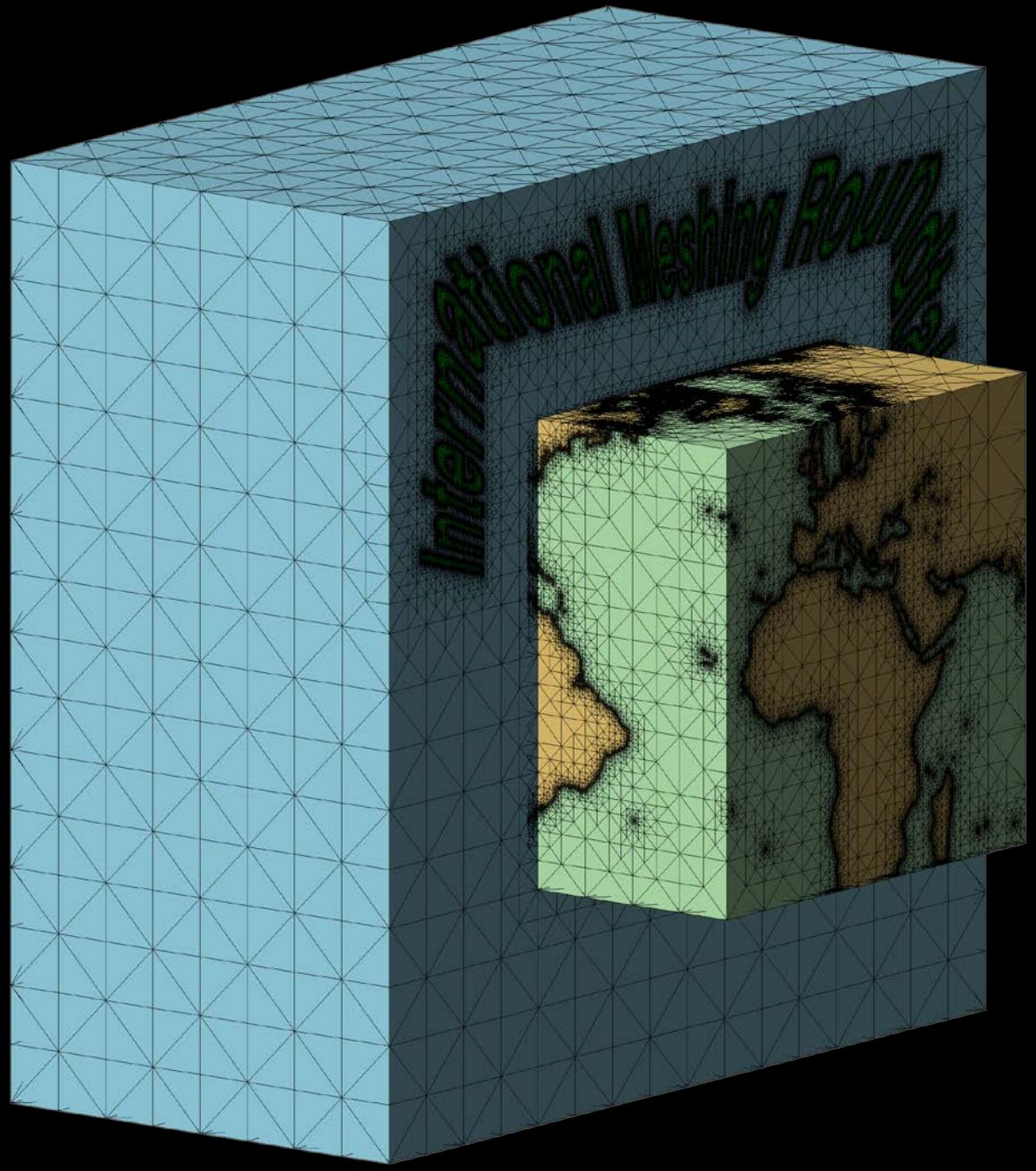


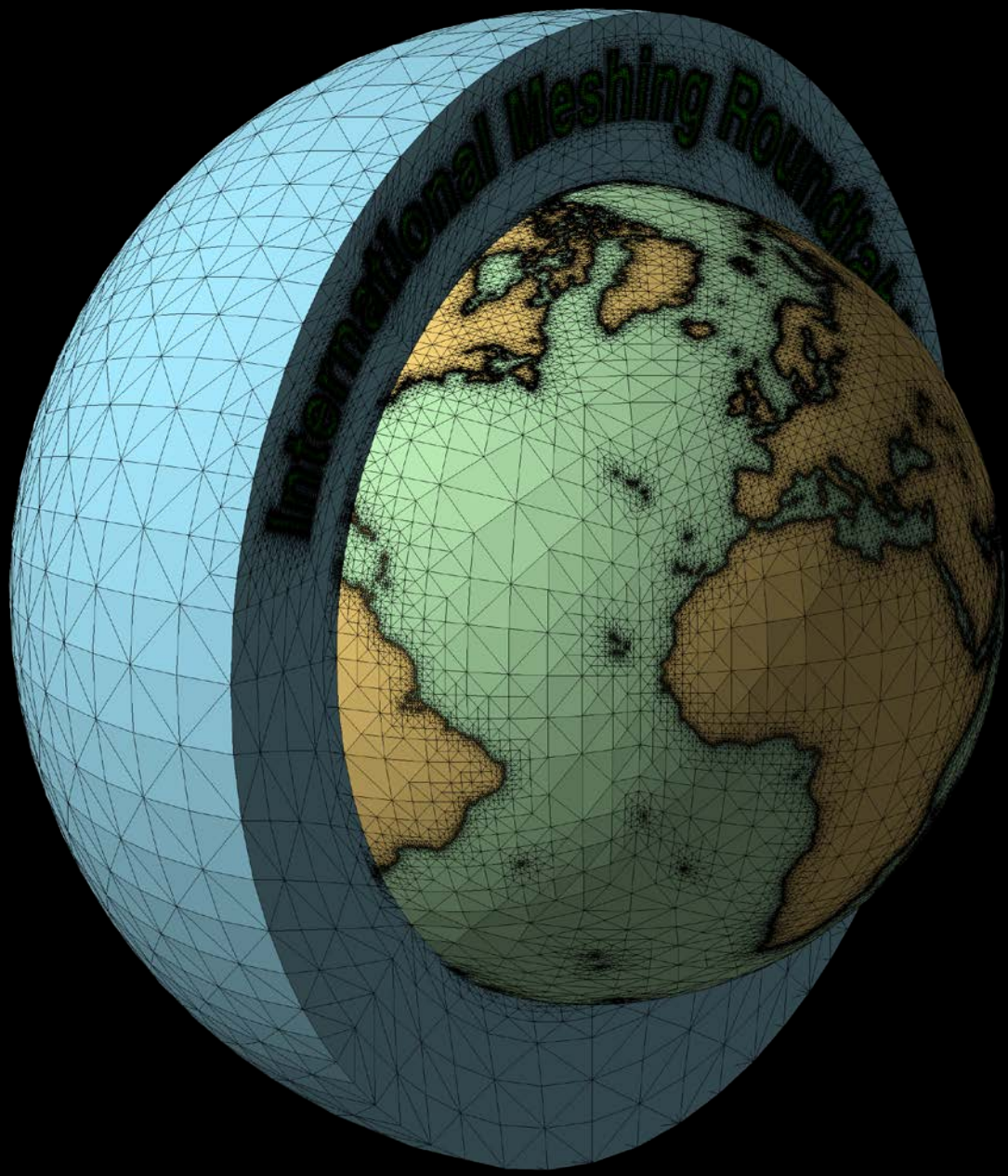
16th IMR (2007)

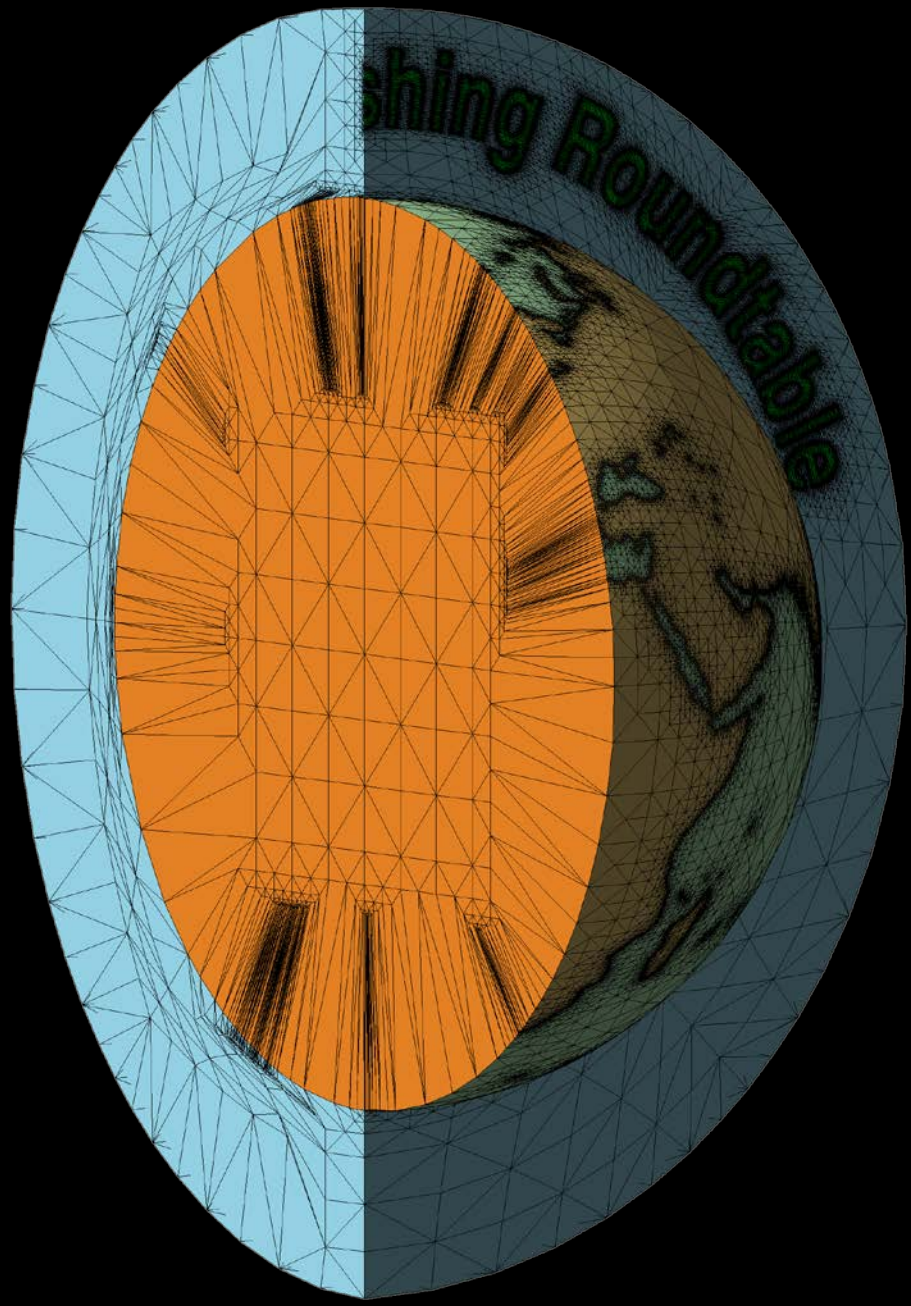


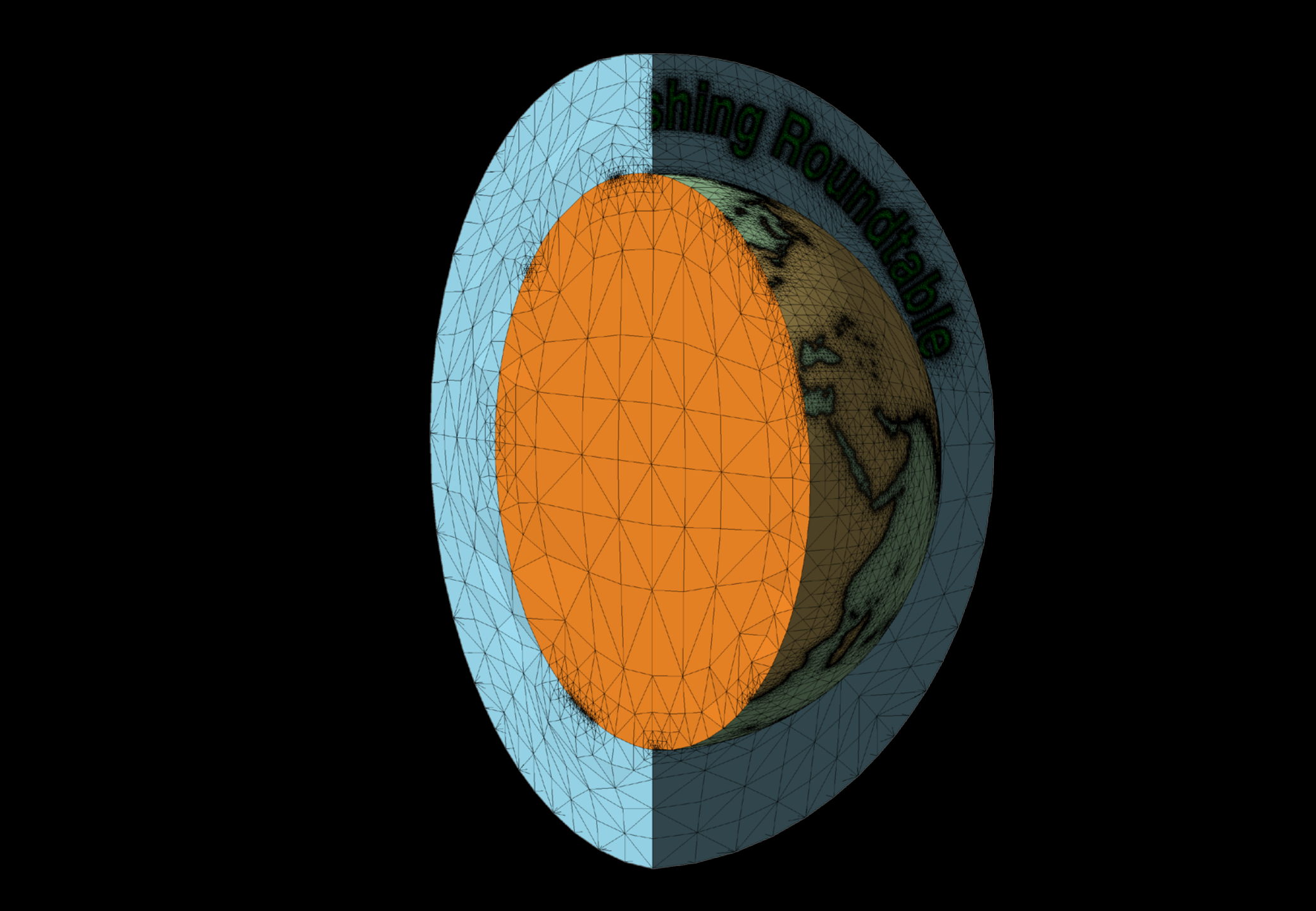


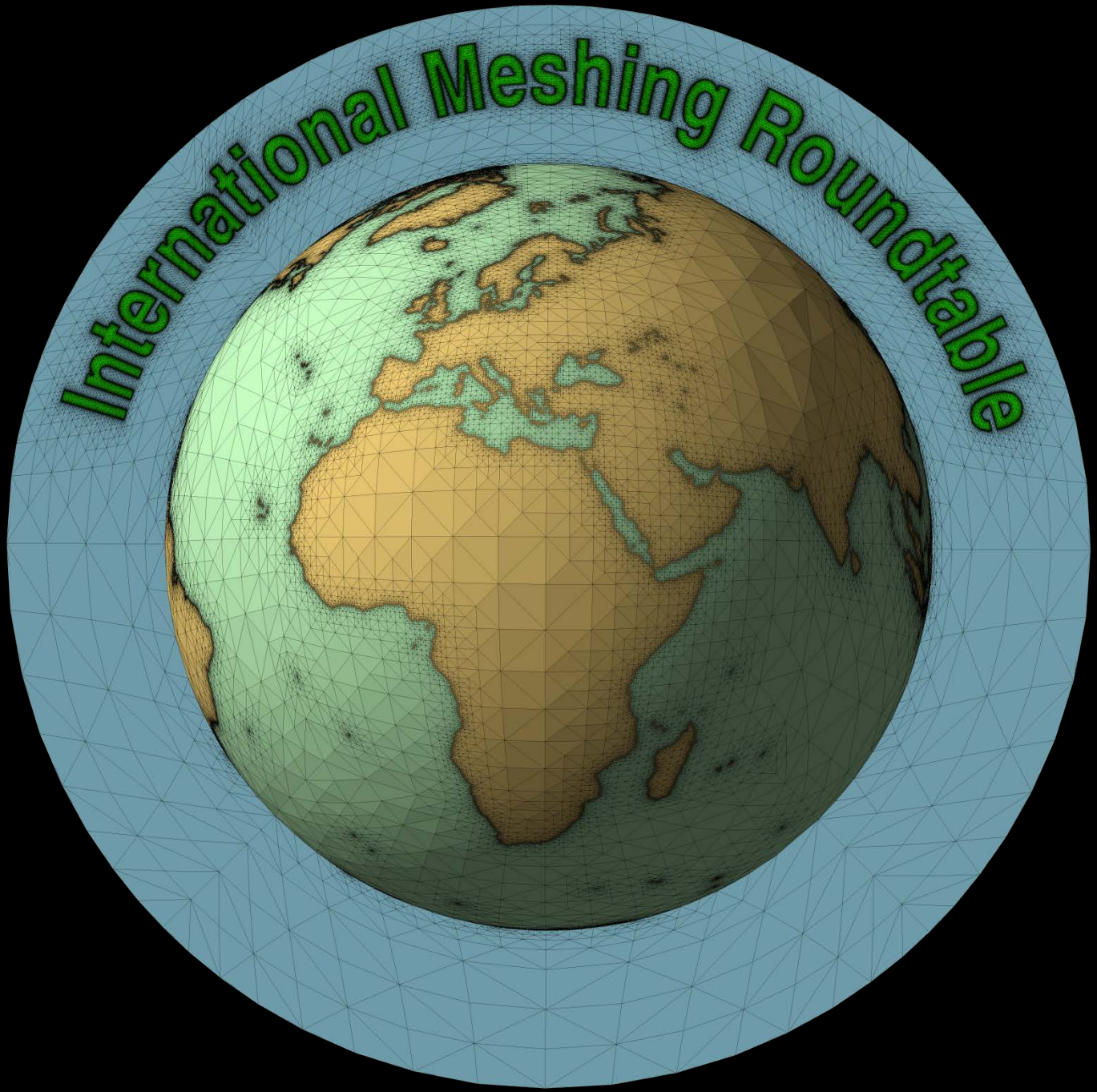



International Meshing Roundtable

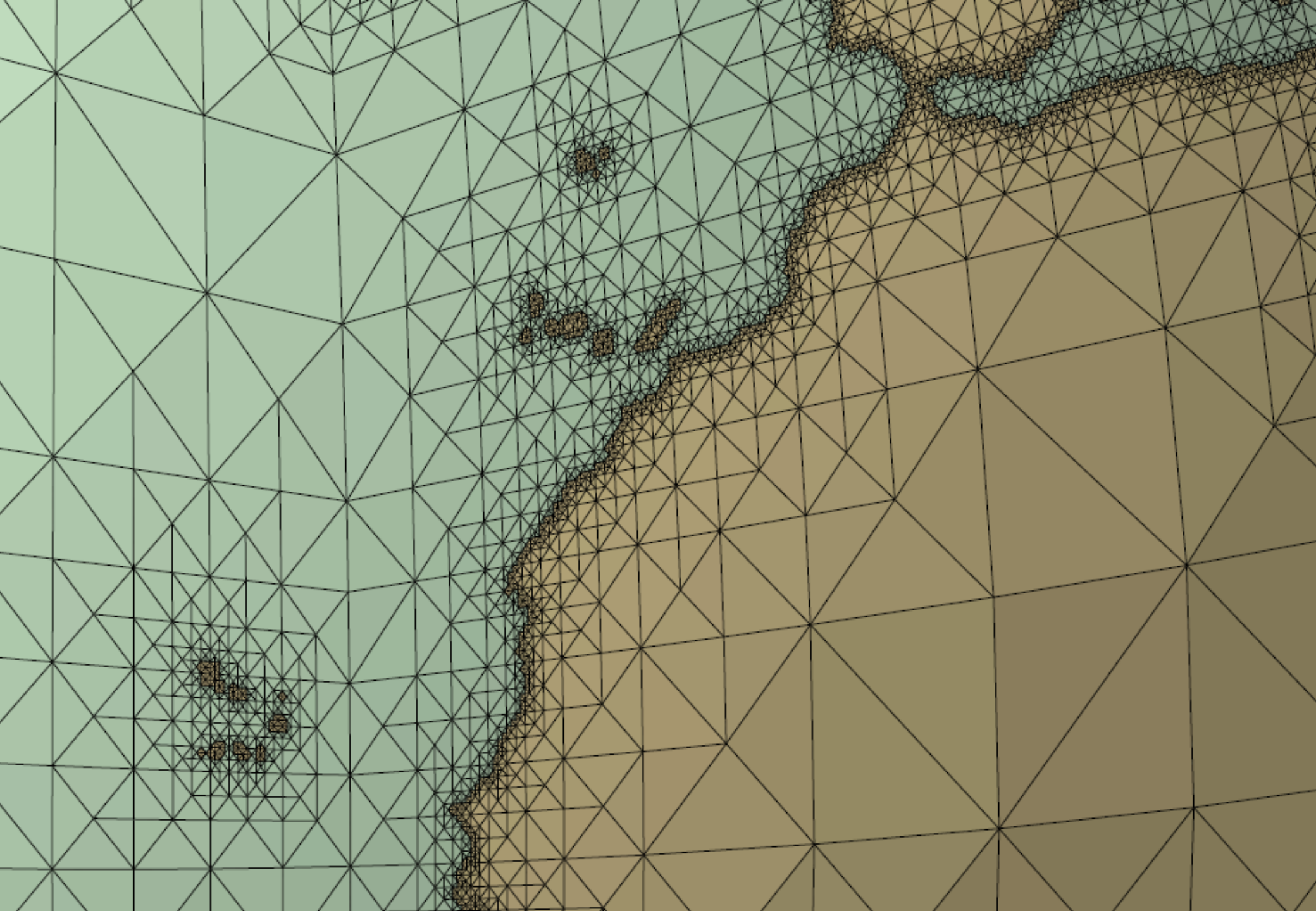

International Meshing Roundtable


shing Roundtable


shing Roundtable


International Meshing Roundtable


Universidad de Las Palmas de Gran Canaria
www.ulpgc.es



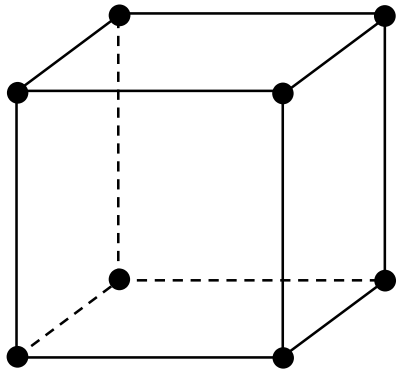
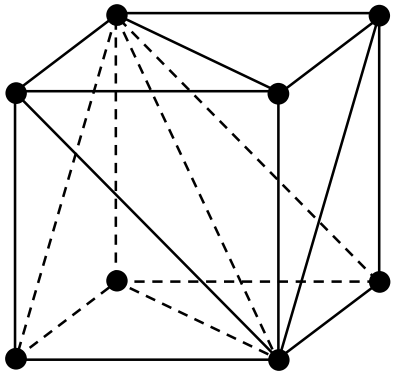
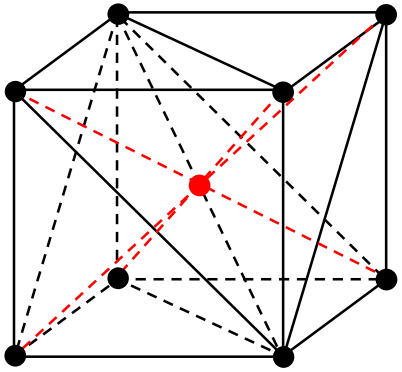
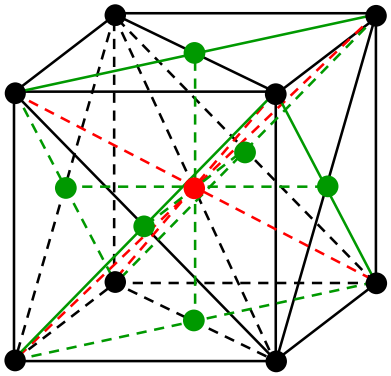
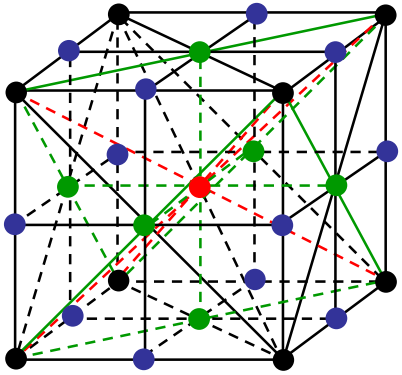
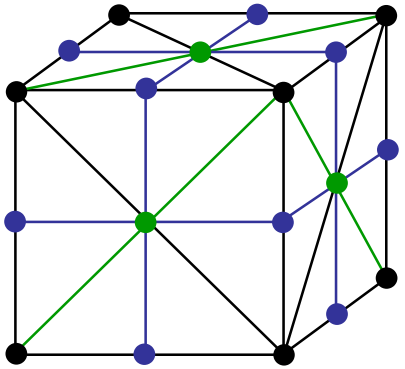
Local Refinement: Kossaczky's Algorithm (JCAM 1994)

Refinement of a cube

http://www.alberta-fem.de/, ALBERTA code

SIANI

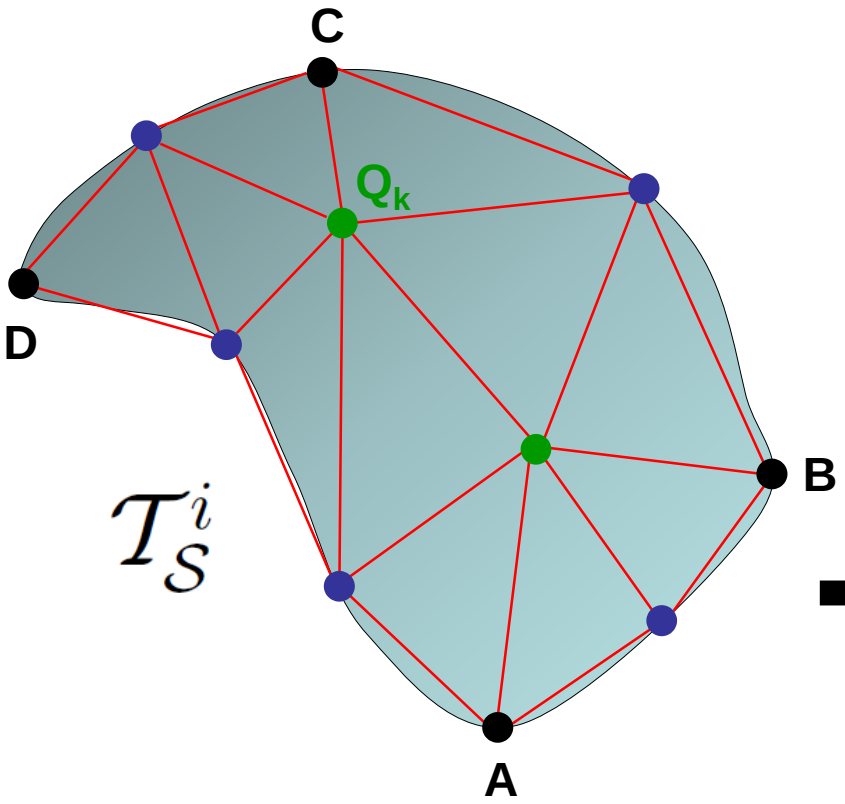
- Initial cube and its subdivision after three consecutive tetrahedron bisection

Surface Parameterization of M.S. Floater (CAGD 1997)

From a the *i-th* solid surface triangulation patch to the *i-th* meccano face

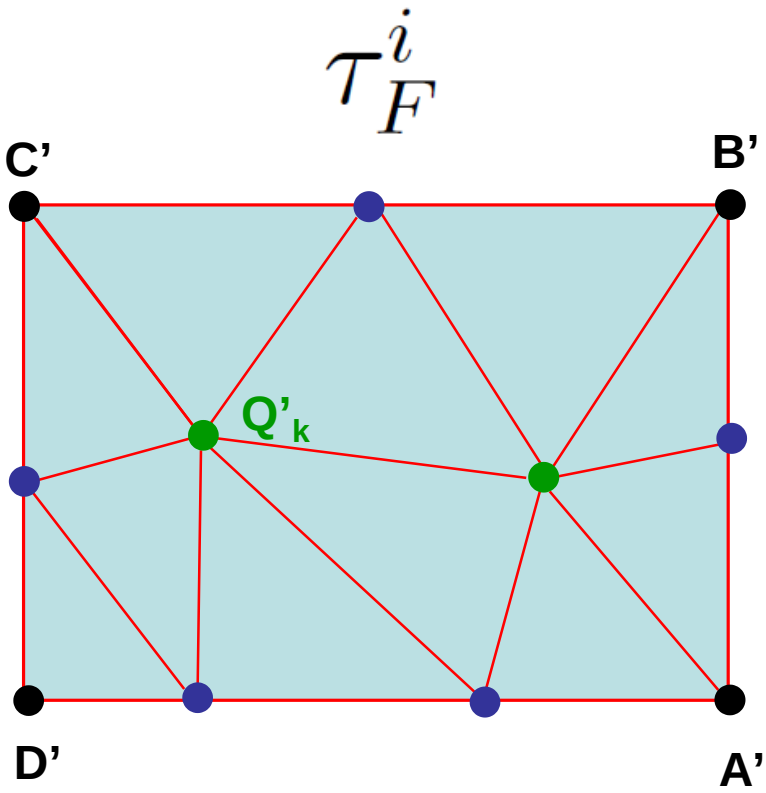
http://www.sintef.no/math software, GoTools from SINTEF ICT



Physical Space

Fixed boundary nodes,

$Q'_k = \sum_j \lambda_{j,k} Q'_j$



Parametric Space

Simultaneous Untangling and Smoothing (CMAME 2003)

Case of plane triangulations

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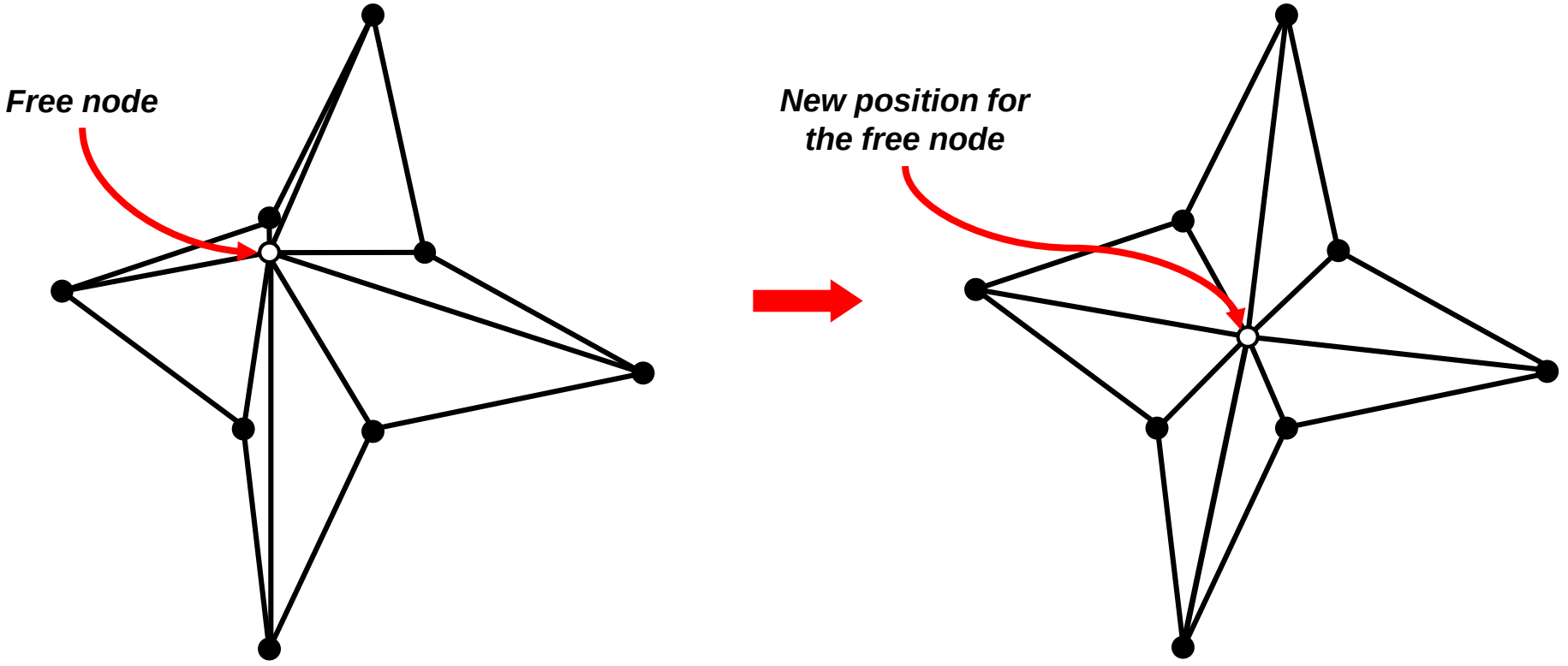
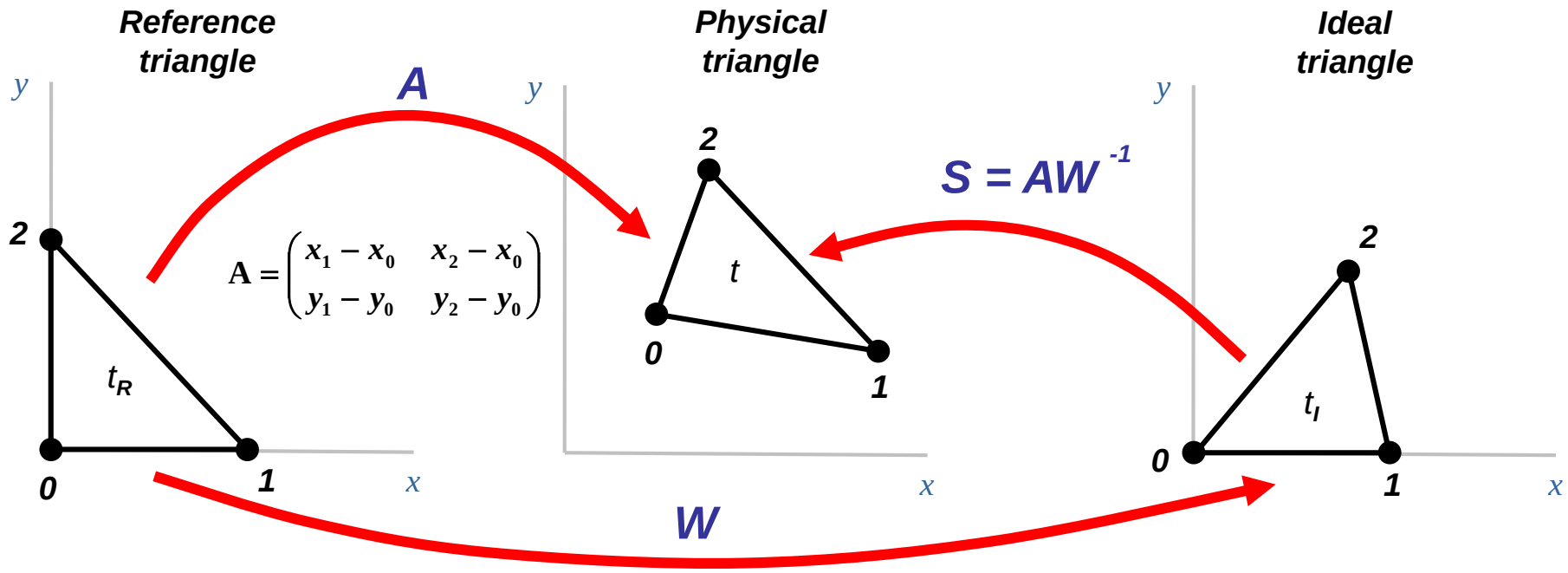
Local optimization

Objective: ***Improve the quality of the local mesh by minimizing an objective function***



Simultaneous Untangling and Smoothing (CMAME 2003)

Weighted Jacobian Matrix on a Plane



$t_I \xrightarrow{S} t$ $\quad S = AW^{-1}$: **Weighted Jacobian matrix**

An algebraic quality metric of t (mean ratio)

$$q = \frac{2\sigma}{\|S\|^2} = \frac{1}{\eta}$$

where:

$$\|S\| = \sqrt{\mathrm{tr}\left(S^T S\right)}$$

$$\sigma = \det(S)$$

Simultaneous Untangling and Smoothing (CMAME 2003)

Local objective function for plane triangulations

SUS Code: Freely-available in http://www.dca.iusiani.ulpgc.es/proyecto2012-2014

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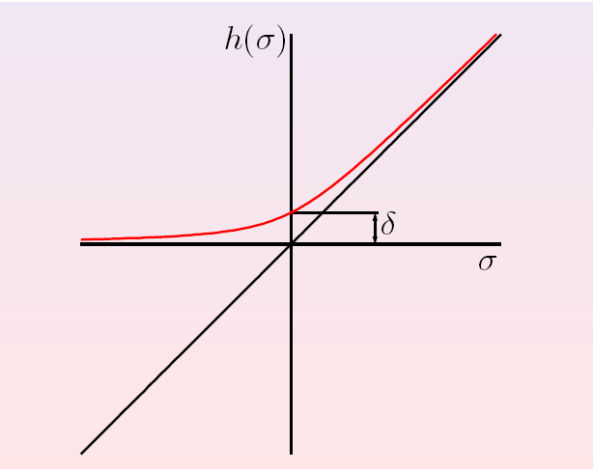
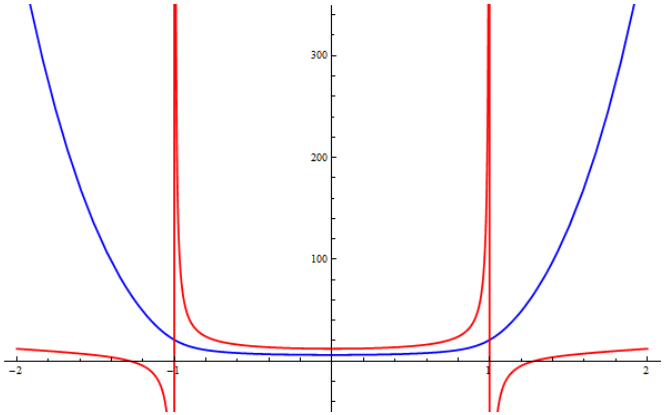
Original function: $$K(\mathbf{x}) = \sum_{m=1}^{M} \frac{\|S_m\|^2}{2\,\sigma_m}$$

Modified function: $$K^*(\mathbf{x}) = \sum_{m=1}^{M} \frac{\|S_m\|^2}{2h\,(\sigma_m)}$$



$$h(\sigma) = \tfrac{1}{2}(\sigma + \sqrt{\sigma^2 + 4\delta^2})$$



Modified function (blue) is regular in all R^2 and it approximates the same minimum that the original function (red). Moreover, it allows a simultaneous untangling and smoothing of triangular meshes

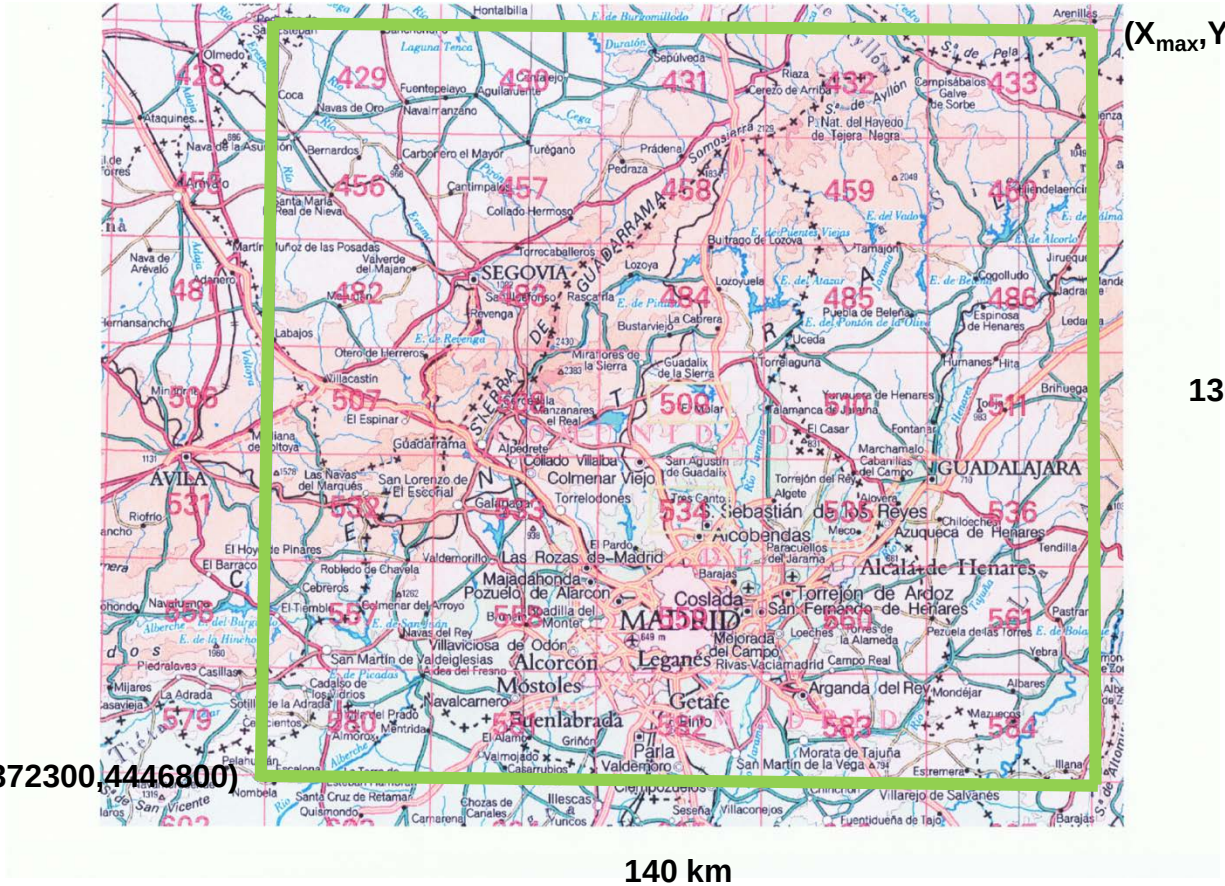
The extension to tetrahedral meshes is straightforward:

$$\eta_m = \frac{|S_m|^2}{3[h(\sigma_m)]^{\frac{2}{3}}}$$

Meccano Method for Tetrahedral Mesh Generation

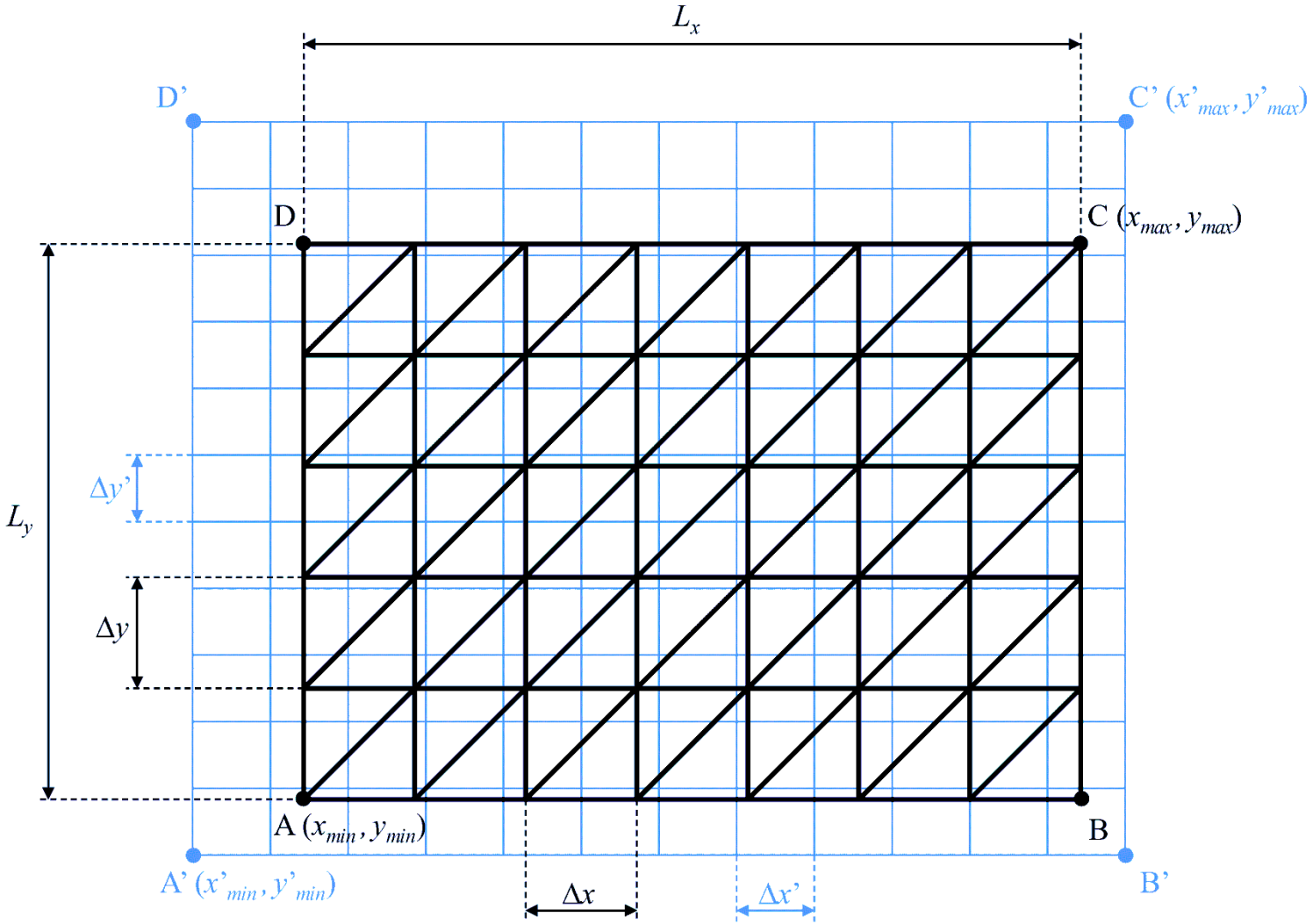
Madrid: Centro Nacional de Información Geográfica, step 25 m

http://www.cnig.es/



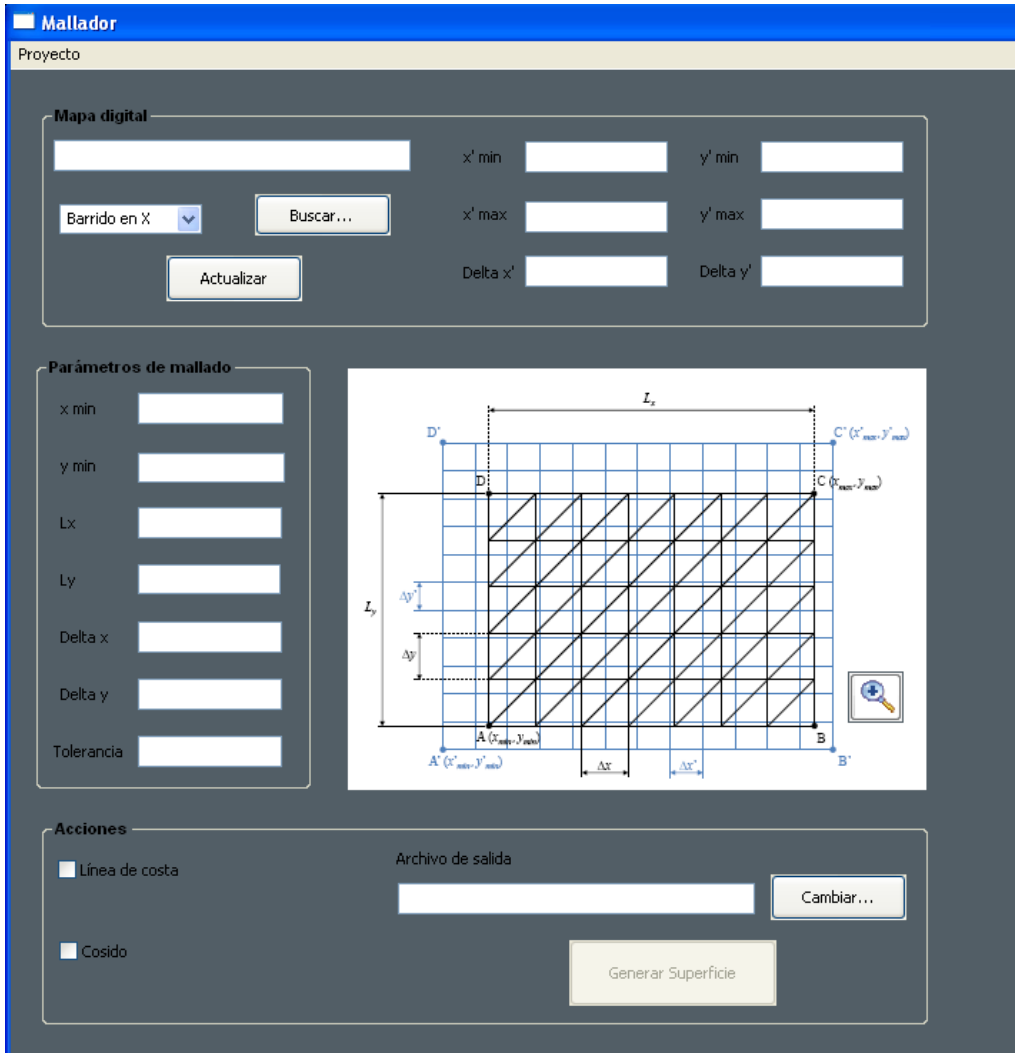
Meccano Method for Tetrahedral Mesh Generation

The Mesh Generation Code (Prototype)



Meccano Method for Tetrahedral Mesh Generation

The Mesh Generation Code (Prototype)



Meccano Method for Tetrahedral Mesh Generation

Madrid: Elevation between 416 m and 2430 m

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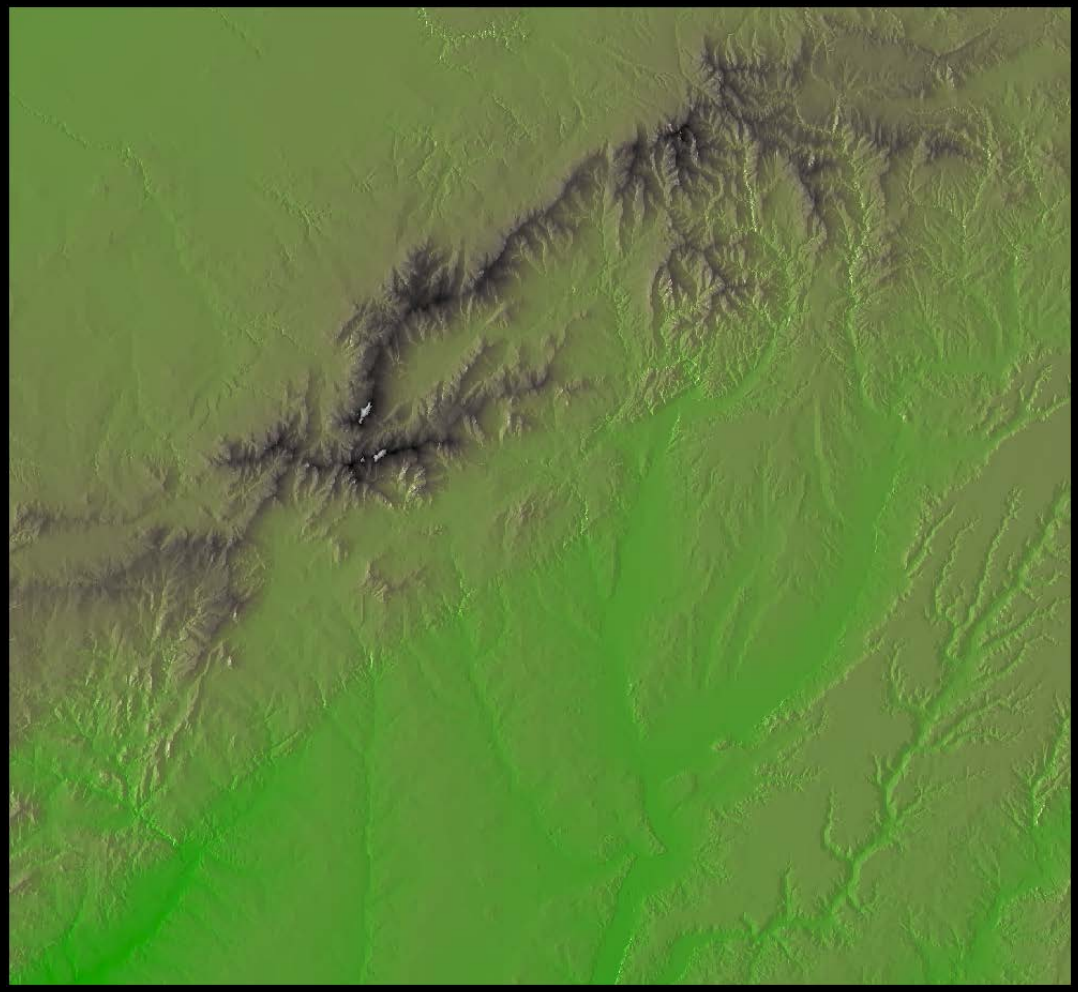
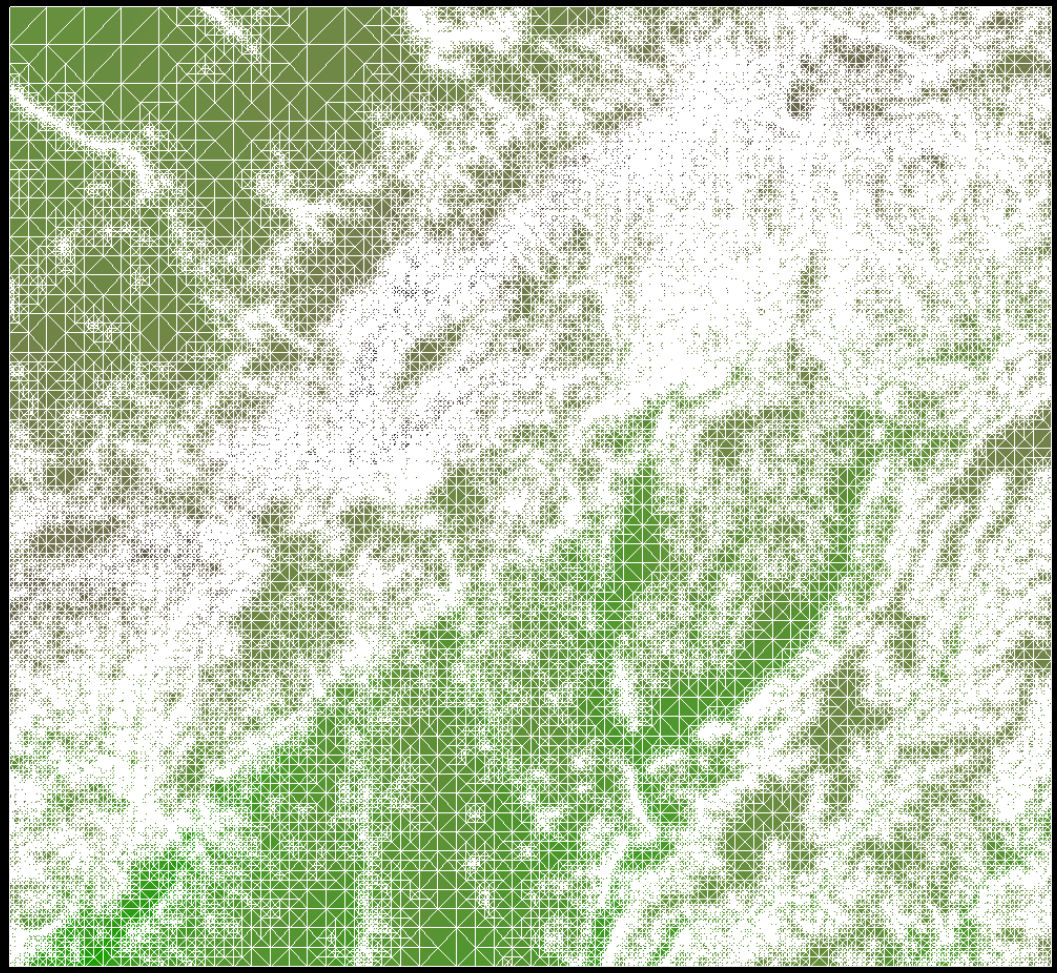


Meccano Method for Tetrahedral Mesh Generation

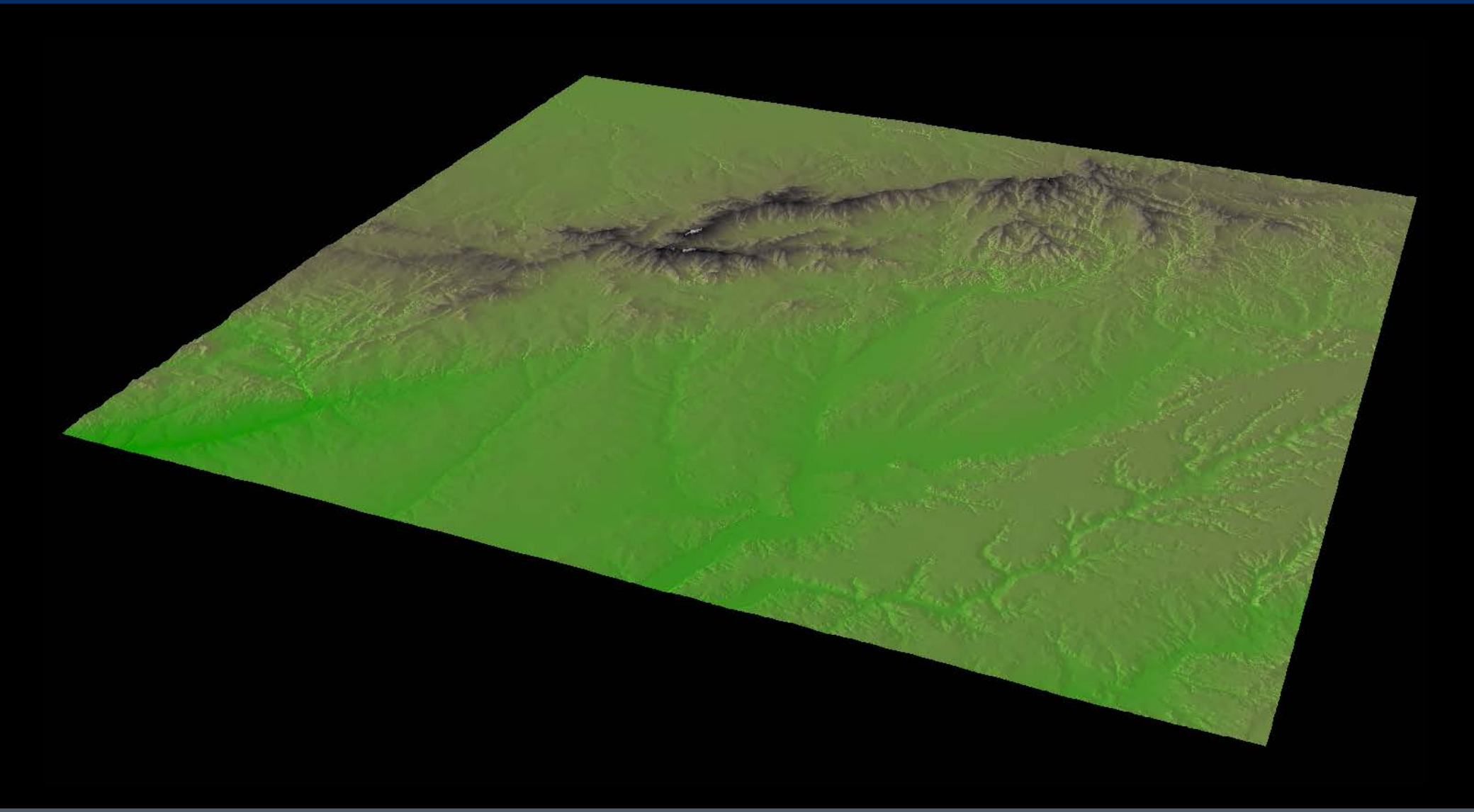
Madrid: 171911 nodes on the terrain surface



Meccano Method for Tetrahedral Mesh Generation

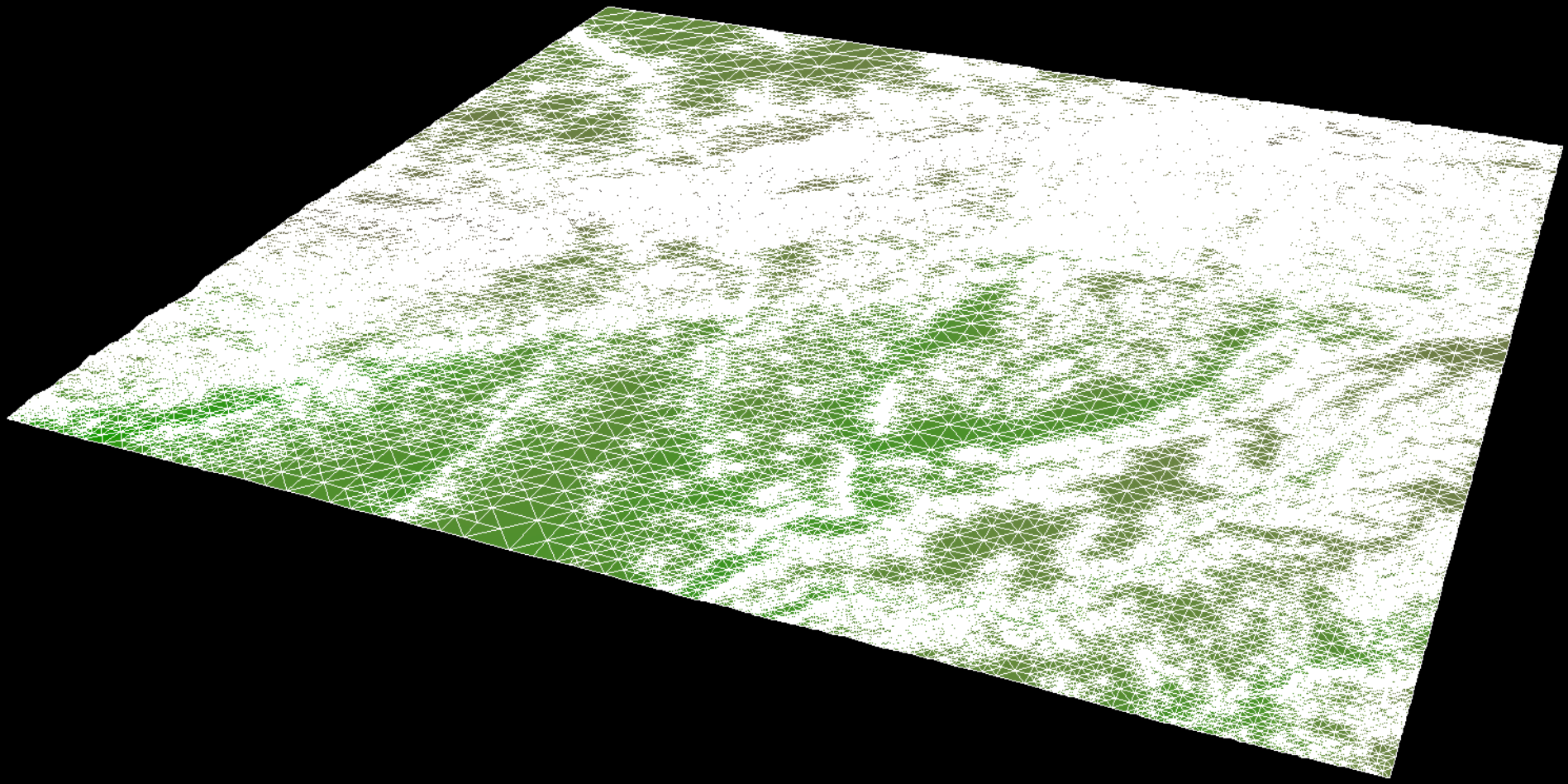
Madrid: Elevation between 416 m and 2430 m

SIANI



Meccano Method for Tetrahedral Mesh Generation

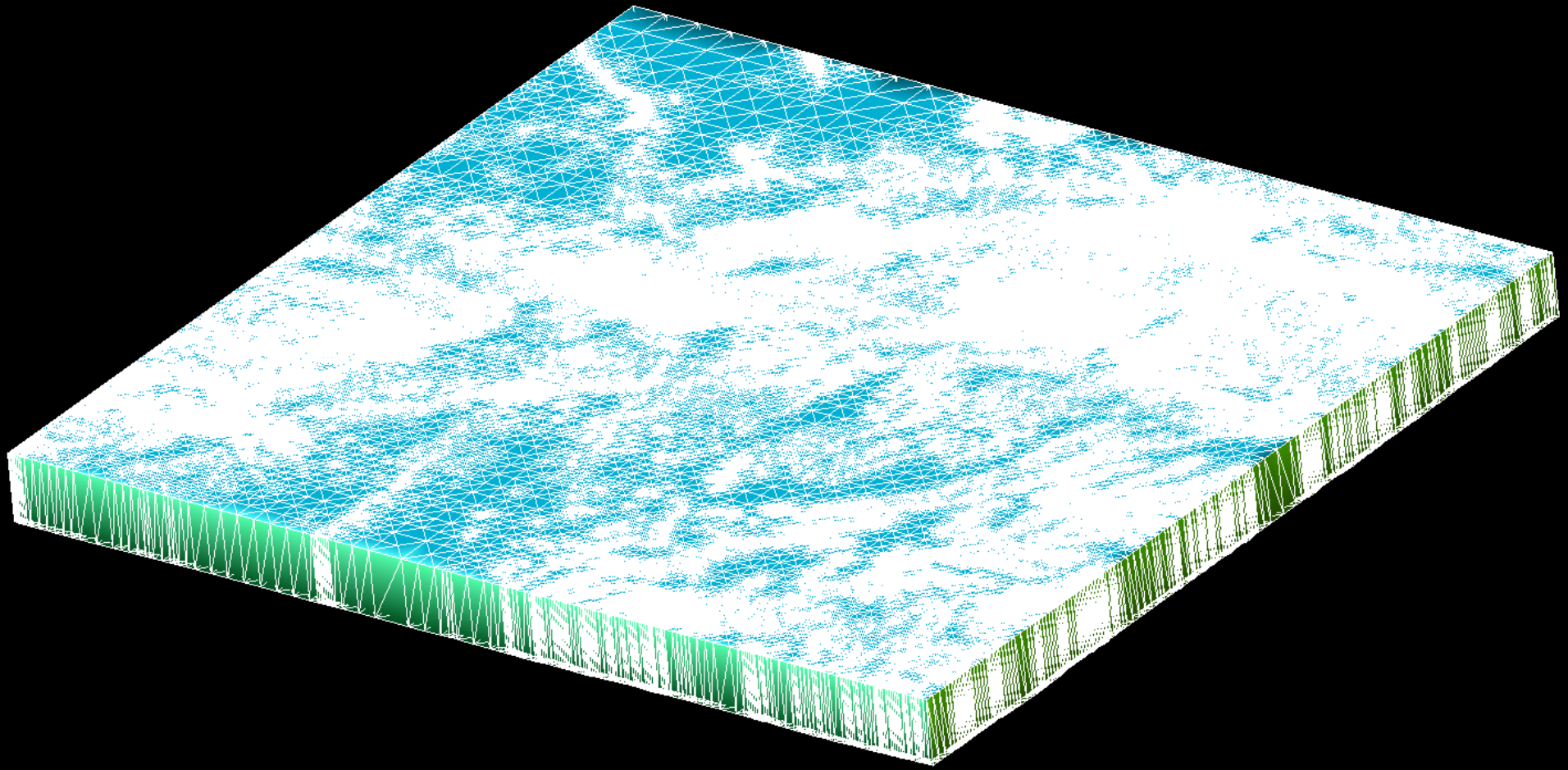
Madrid: 171911 nodes on the terrain surface



Meccano Method for Tetrahedral Mesh Generation

Madrid: Transient surface triangulation of the 3-D domain

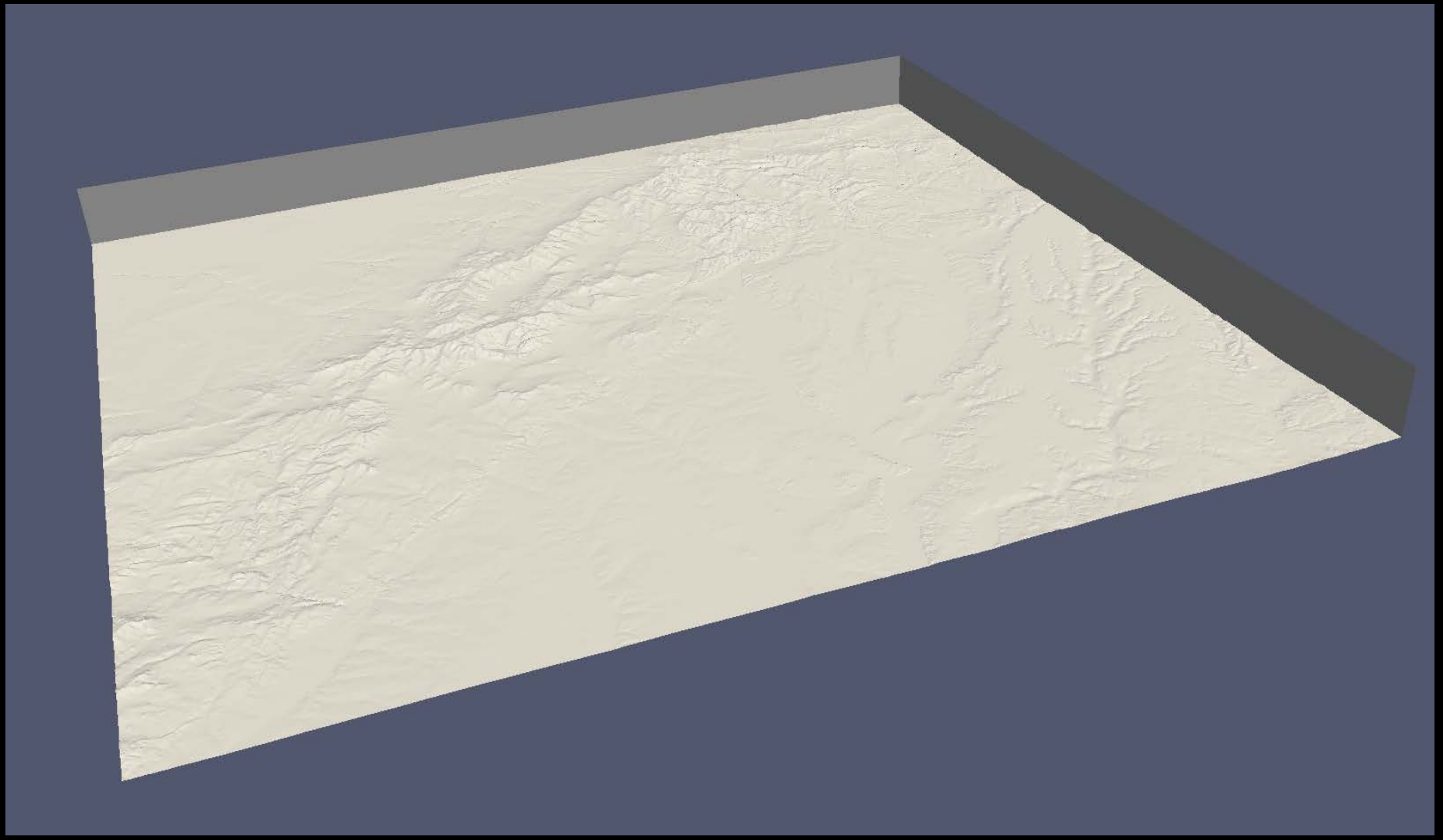
SIANI



Meccano Method for Tetrahedral Mesh Generation

Madrid: 3-D domain; the upper plane is placed at 10 km

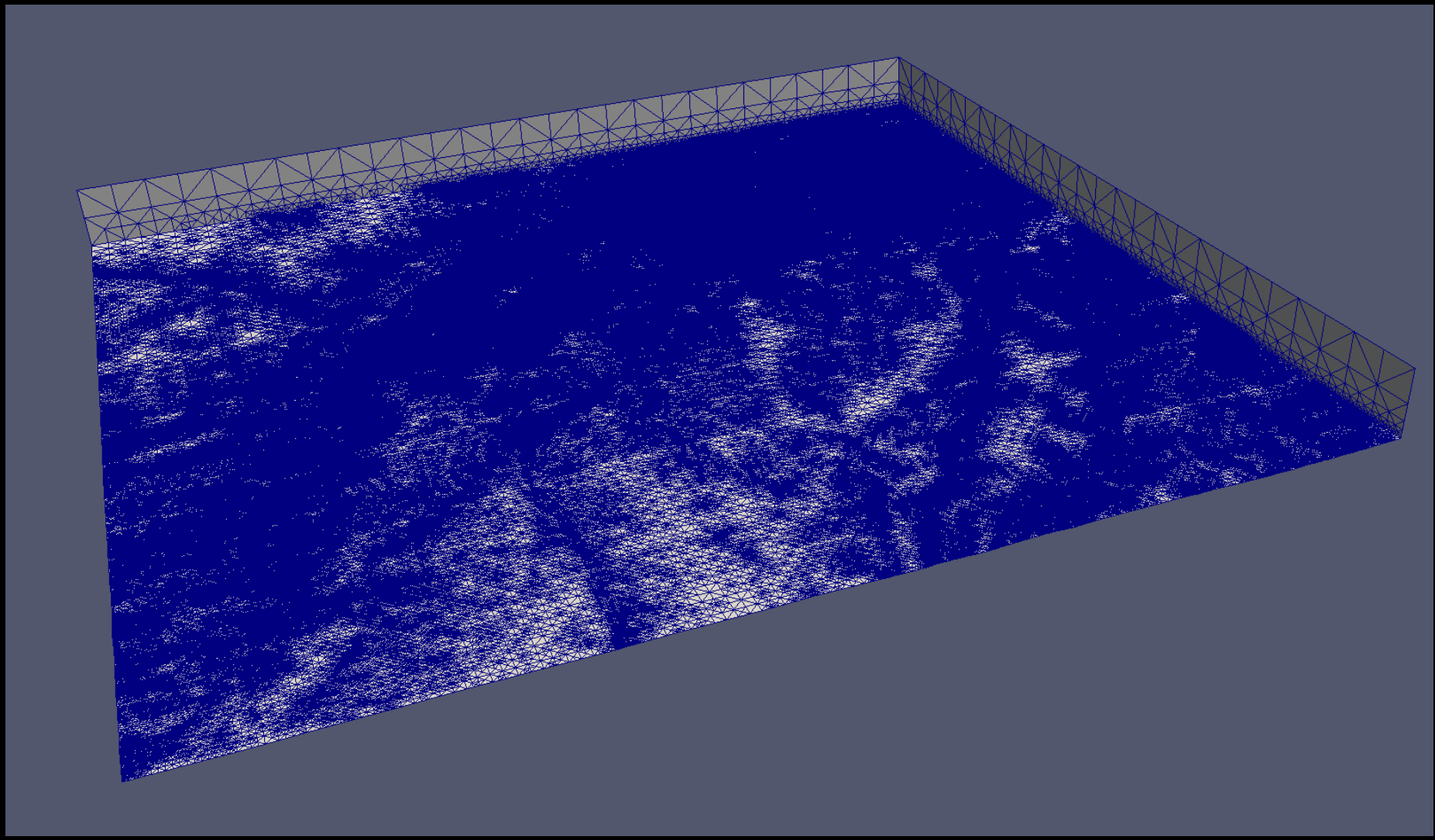
SIANI



Meccano Method for Tetrahedral Mesh Generation

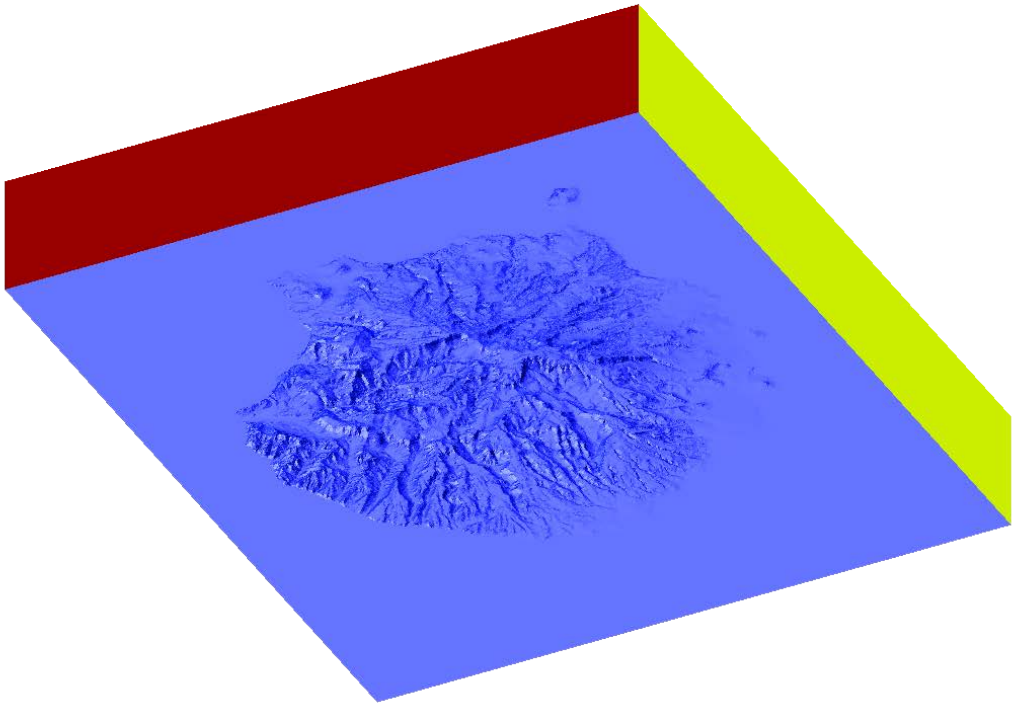
Madrid: Tetrahedral mesh with 824.379 nodes and 3.569.164 tetrahedra

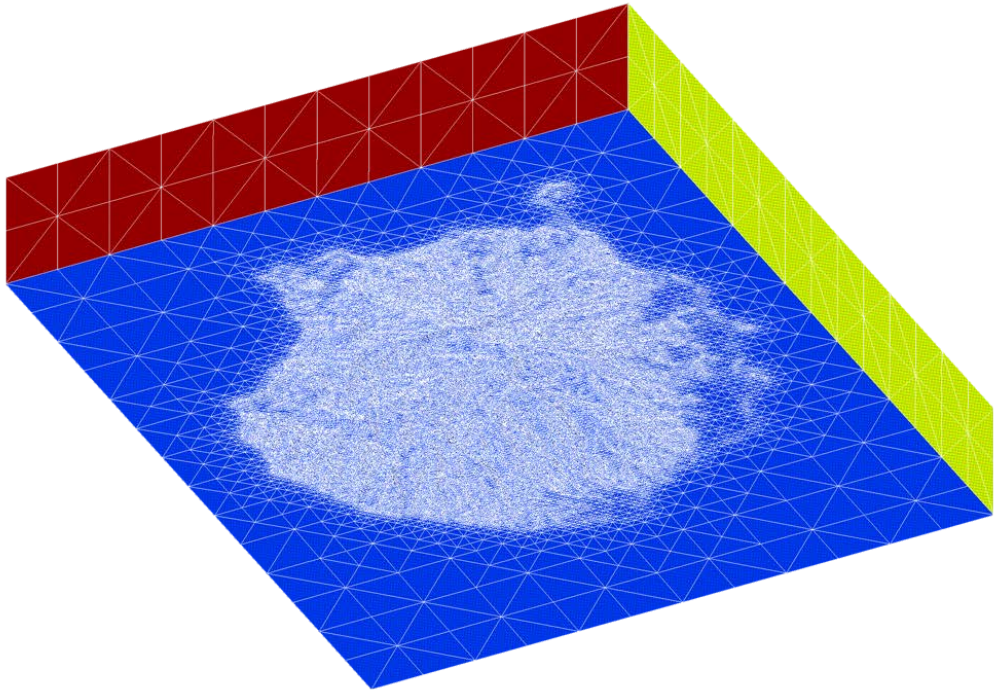
$q_{min} = 0.17$; $q_{mean} = 0.77$; only 3 tetrahedra with $q < 0.3$



Meccano Method for Tetrahedral Mesh Generation

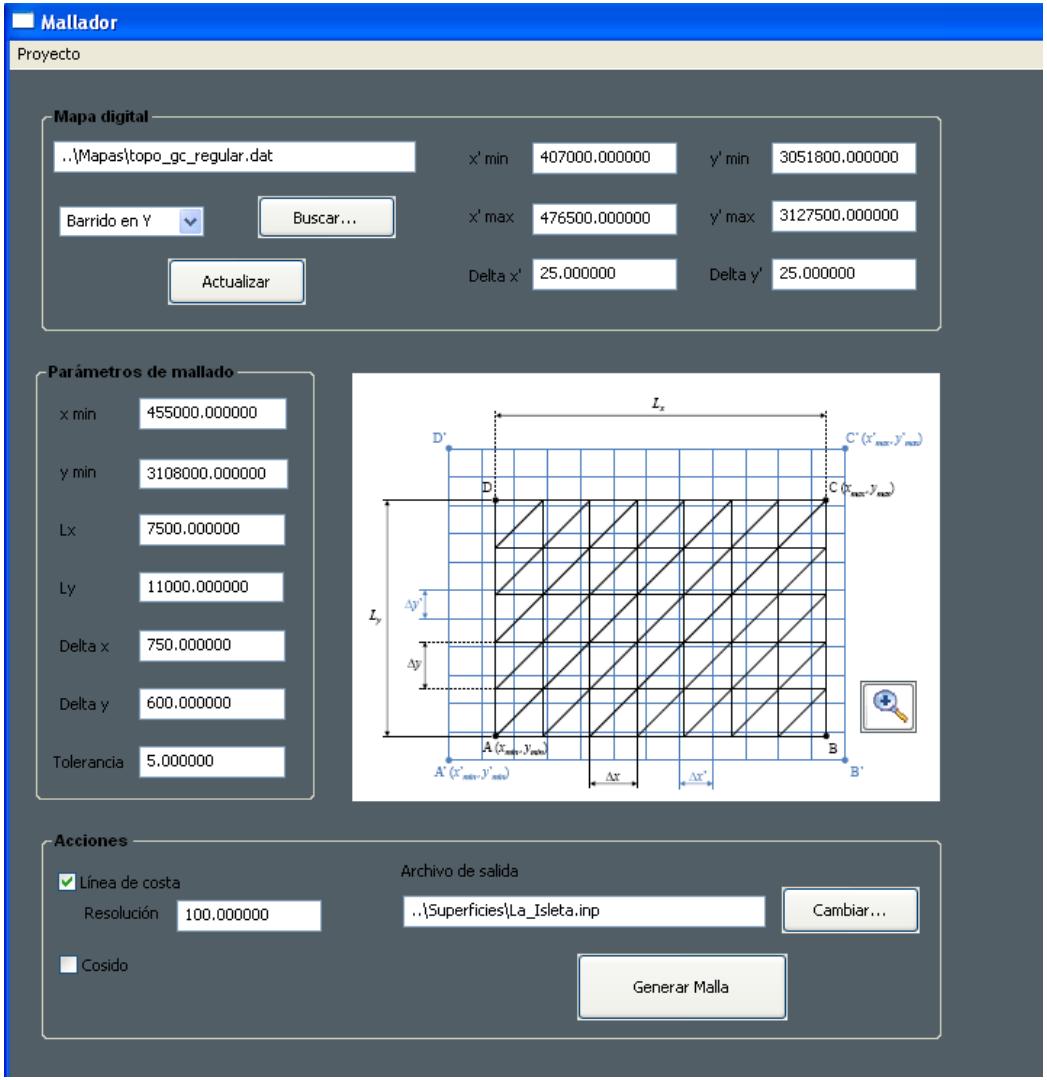
Application to Gran Canaria Island





Meccano Method for Tetrahedral Mesh Generation

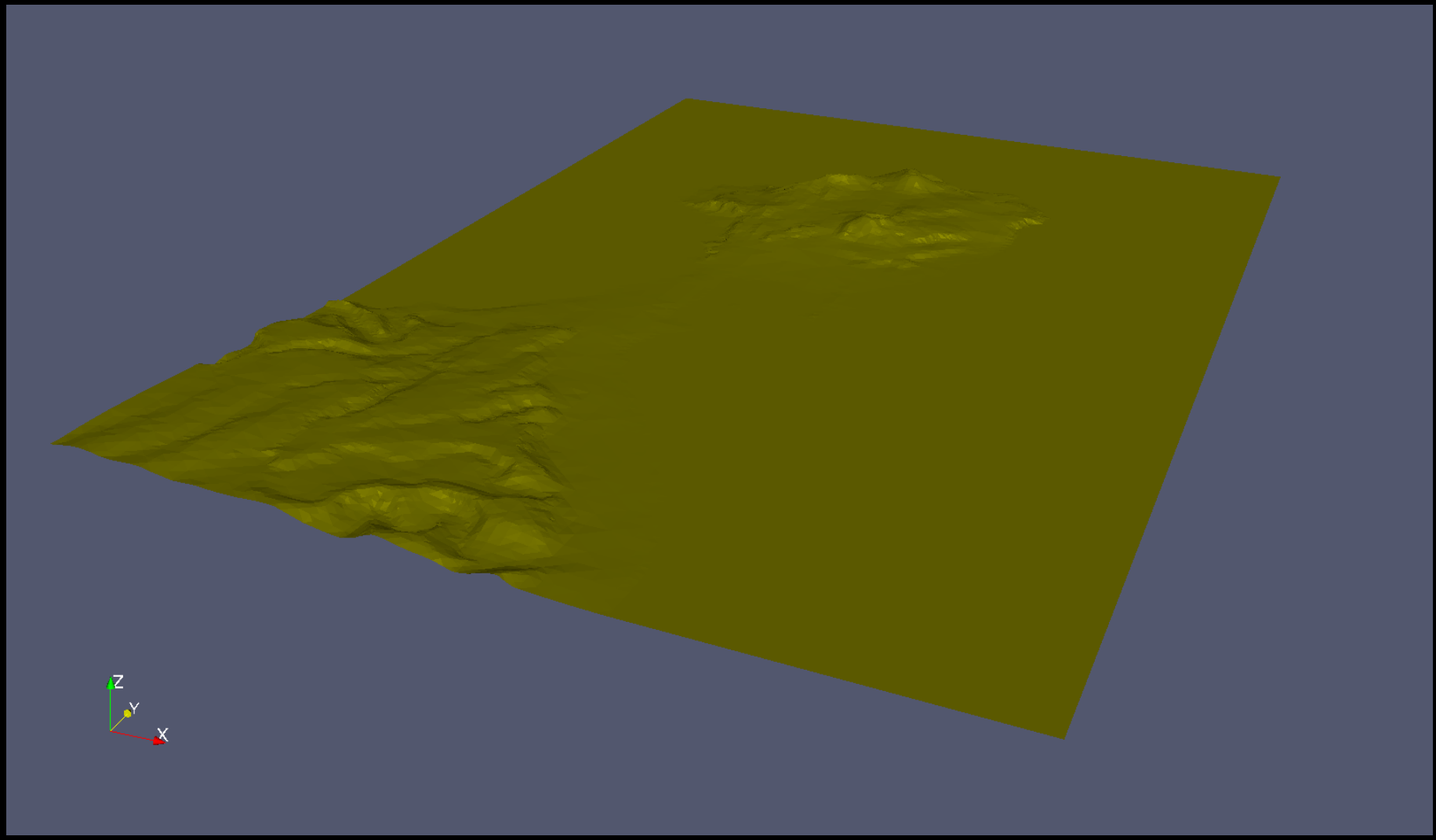
Gran Canaria: The city of Las Palmas de Gran Canaria (Input Data)



Meccano Method for Tetrahedral Mesh Generation

Gran Canaria: The city of Las Palmas de Gran Canaria (Orography)

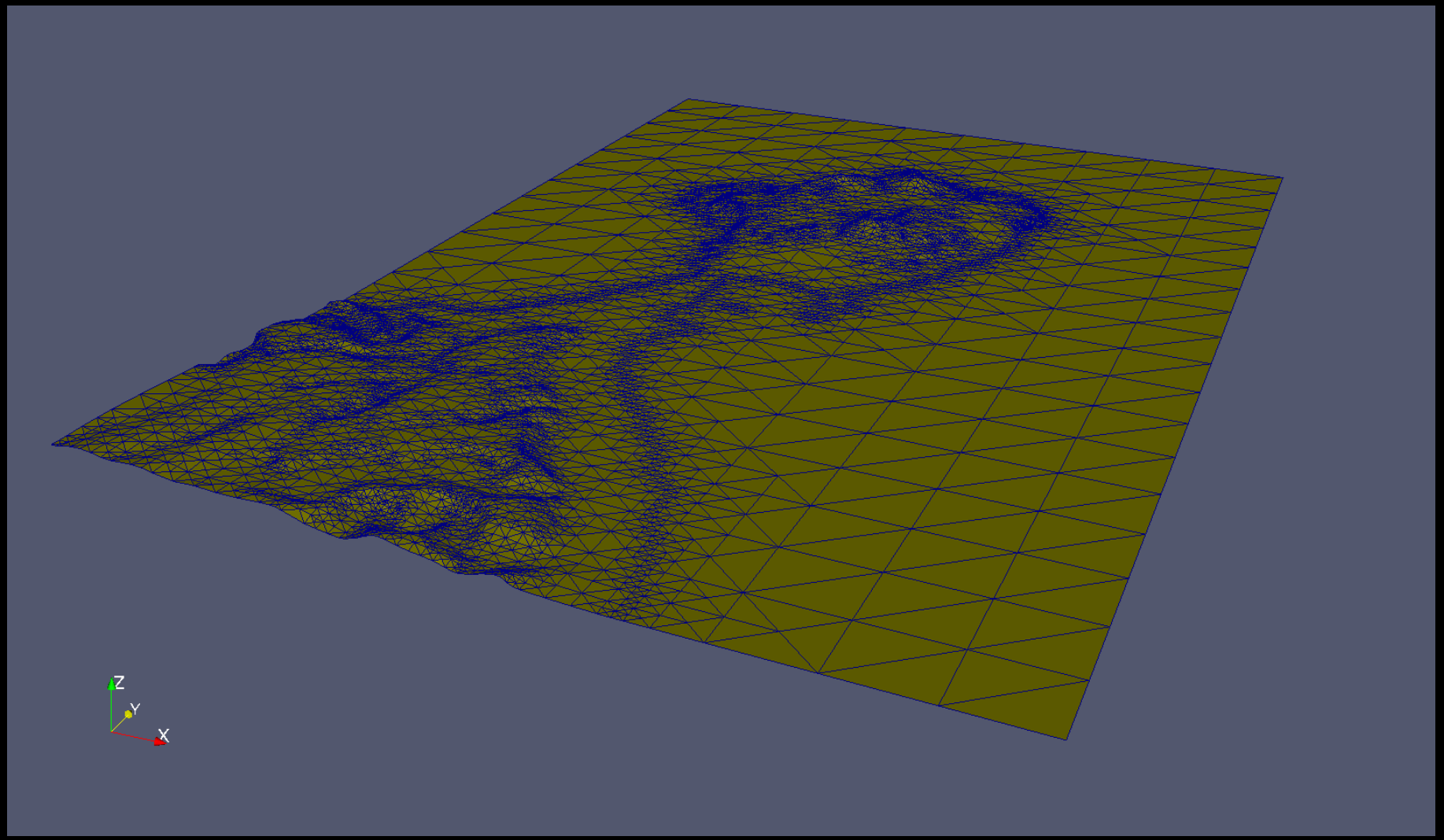
SIANI

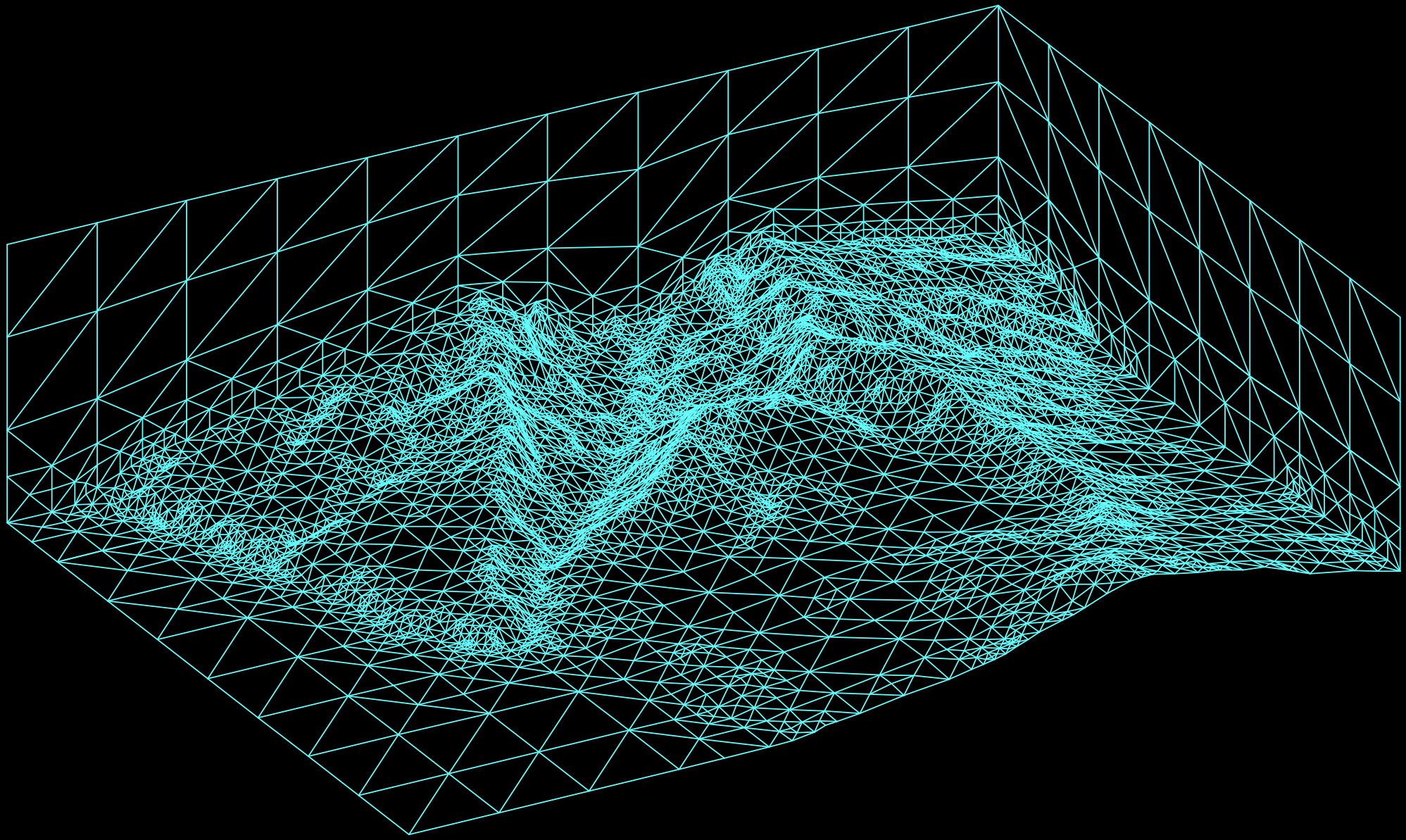


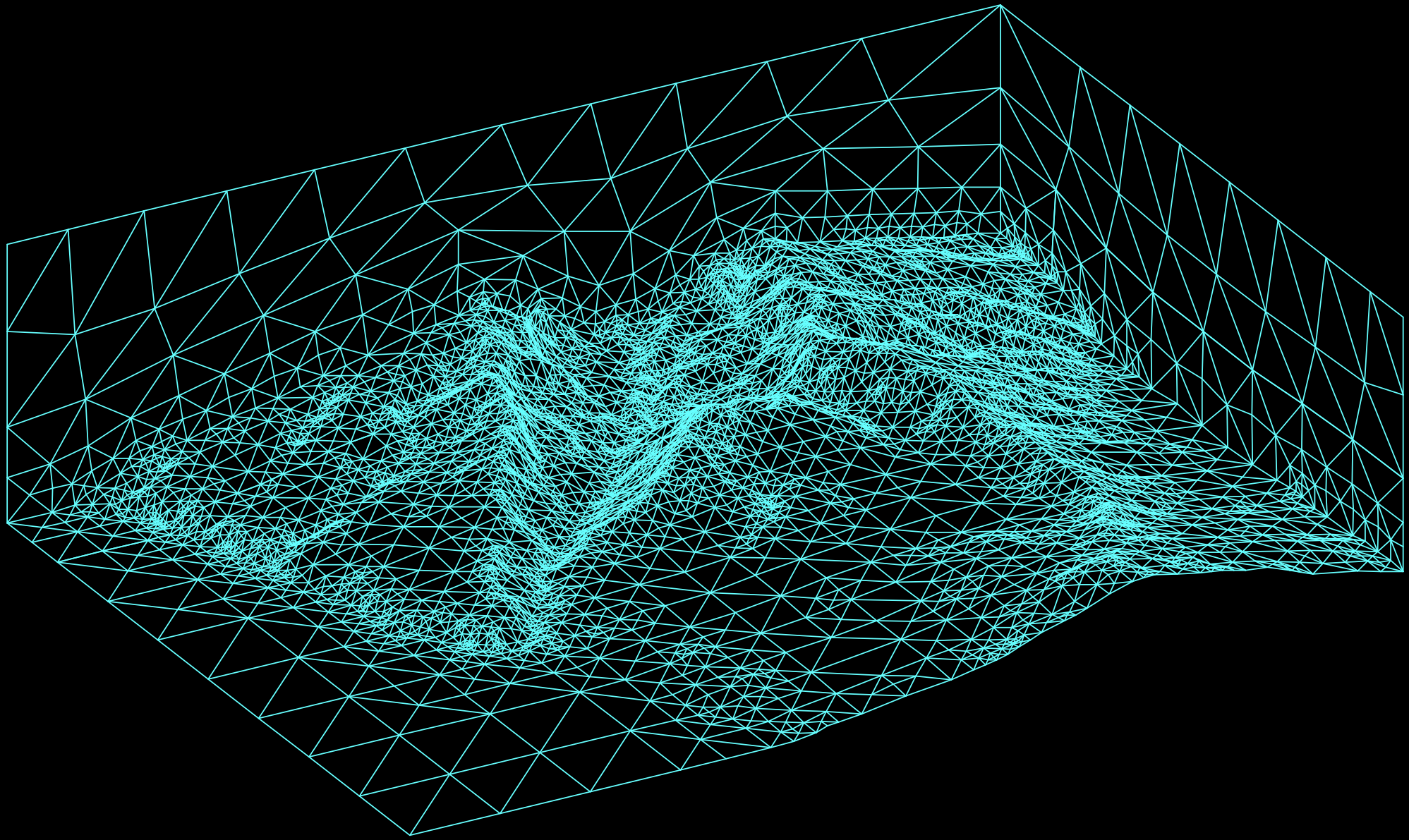
Meccano Method for Tetrahedral Mesh Generation

Gran Canaria: The city of Las Palmas de Gran Canaria (The Mesh)

SIANI

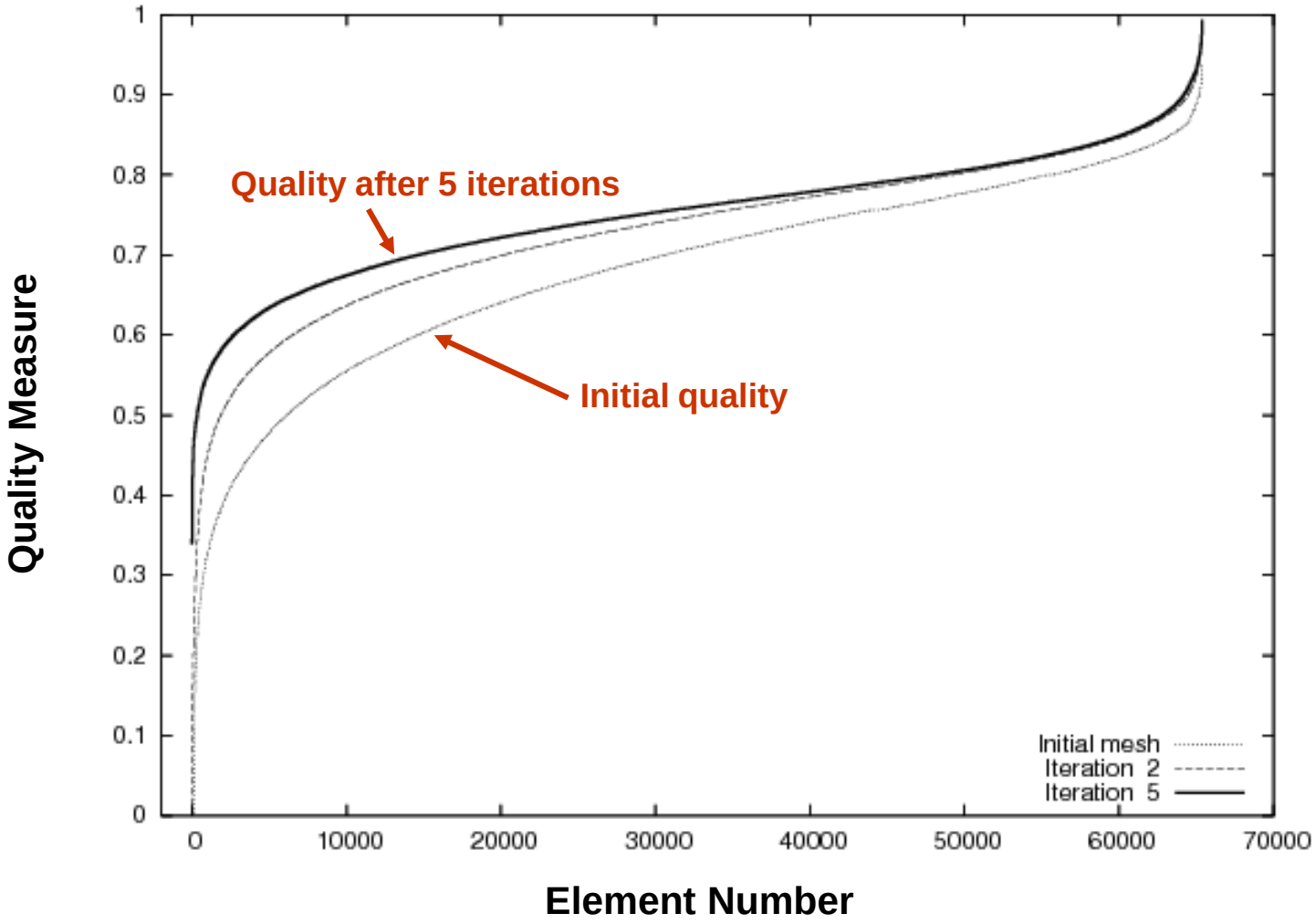






Tetrahedral Mesh Quality Curves

La Palma Island



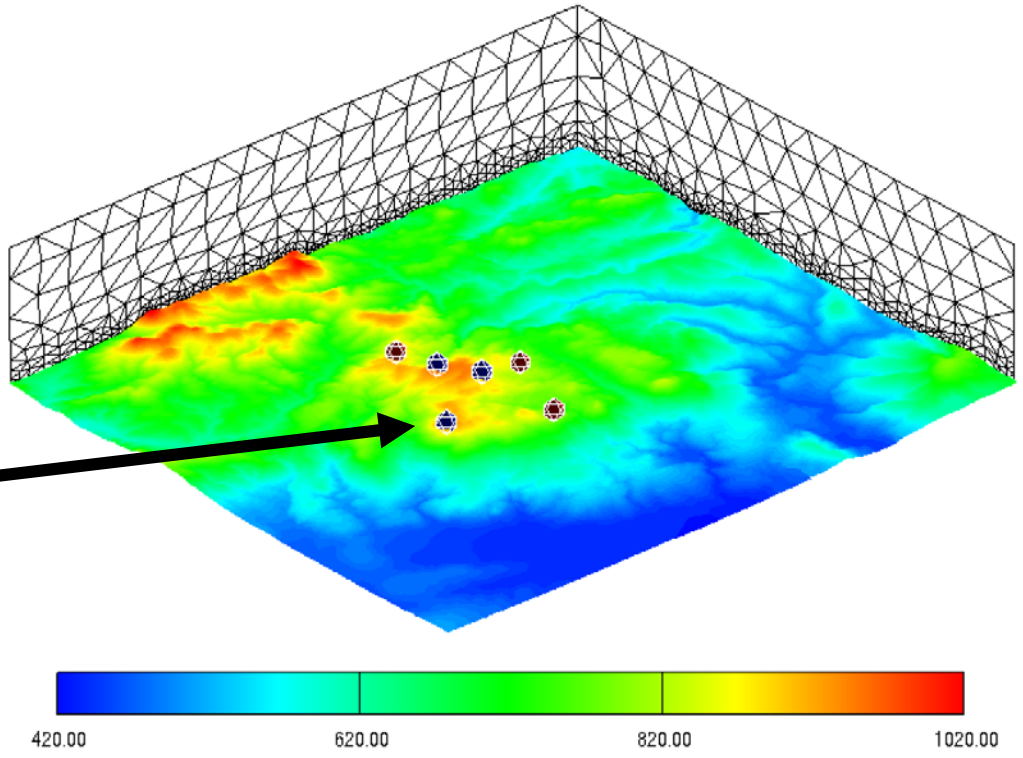
The Wind Field Model

Mass Consistent Wind Model

Mathematical aspects

Let $\Omega \subset \mathrm{R}^3$ be a domain with boundary $\Gamma = \Gamma_a \cup \Gamma_b$

$\mathbf{u}_0 = (u_0, v_0, w_0)$: observed wind, which is obtained with horizontal interpolation and vertical extrapolation of experimental or forecasted data.

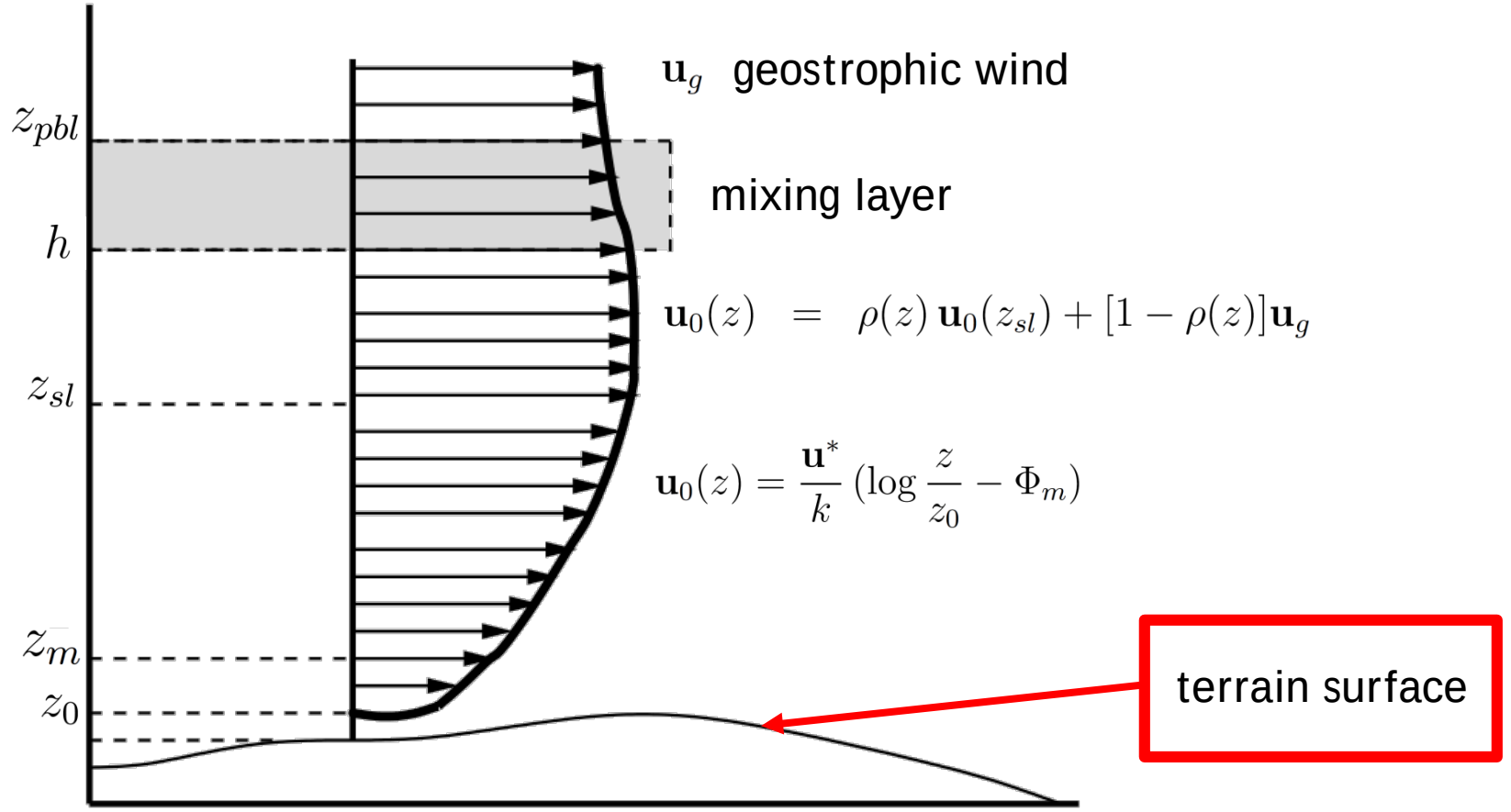


Horizontal interpolation

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

$$0 \leq \xi \leq 1$$

Vertical extrapolation (log-linear wind profile)



Mass Consistent Wind Model

Construction of the observed wind

- **Friction velocity:** $\mathbf{u}^* = \dfrac{k\ \mathbf{u}_0(z_m)}{\log \dfrac{z_m}{z_0} - \Phi_m}$

- **Height of the planetary boundary layer:** $z_{pbl} = \dfrac{\gamma\ |\mathbf{u}^*|}{f}$

  $f = 2\Omega\ \sin\phi$ **is the Coriolis parameter, being** Ω **the Earth rotation and** ϕ **is the latitude**

  γ **is a parameter depending on the atmospheric stability**

- **Mixing height:**

  $h = z_{pbl}$ **in neutral and unstable conditions**

  $h = \gamma' \sqrt{\dfrac{|\mathbf{u}^*|\ L}{f}}$ **in stable conditions**

- **Height of the surface layer:** $z_{sl} = \dfrac{h}{10}$

Mass Consistent Wind Model

Mathematical aspects

Let $\Omega \subset \mathrm{R}^3$ be a domain with boundary $\Gamma = \Gamma_a \cup \Gamma_b$

$\mathbf{u}_0 = (u_0, v_0, w_0)$: observed wind, which is obtained with horizontal interpolation and vertical extrapolation of experimental or forecasted data.

Objective: find the velocity field $\mathbf{u}$ that it adjusts to $\mathbf{u}_0$ verifying

- Incompressibility condition in the domain: $\nabla \cdot \mathbf{u} = 0 \quad \text{in } \Omega$
- Impermeability condition on the terrain: $\mathbf{n} \cdot \mathbf{u} = 0 \quad \text{on } \Gamma_a$

- Then, $\mathbf{u}$ is the solution of the least-square problem: Find $\mathbf{u} \in \mathrm{K}$ verifying

$$\begin{cases} E(\mathbf{u}) = \min_{\mathbf{v} \in \mathrm{K}} E(\mathbf{v}) \\ \mathrm{K} = \left\{ \mathbf{v};\ \nabla \cdot \mathbf{v} = 0,\ \mathbf{n} \cdot \mathbf{v}\big|_{\Gamma_a} = 0 \right\} \end{cases}$$

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

$\alpha = \frac{\alpha_1}{\alpha_2}$

- Lagrange multiplier technique is used to solve this problem. So, if we introduce

$$L(\mathbf{v}, \lambda) = E(\mathbf{v}) + \int_{\Omega} \lambda \nabla \cdot \mathbf{v} \, d\Omega$$

its saddle point $(\mathbf{u}, \phi)$ verifies the Euler-Lagrange equations:

$$-\nabla \cdot \left(\mathbf{P}^{-1} \nabla \phi\right) = \nabla \cdot \mathbf{u}_0 \qquad \text{in } \Omega$$

$$-\mathbf{n} \cdot \mathbf{P}^{-1} \nabla \phi = \mathbf{n} \cdot \mathbf{u}_0 \qquad \text{on } \Gamma_a$$

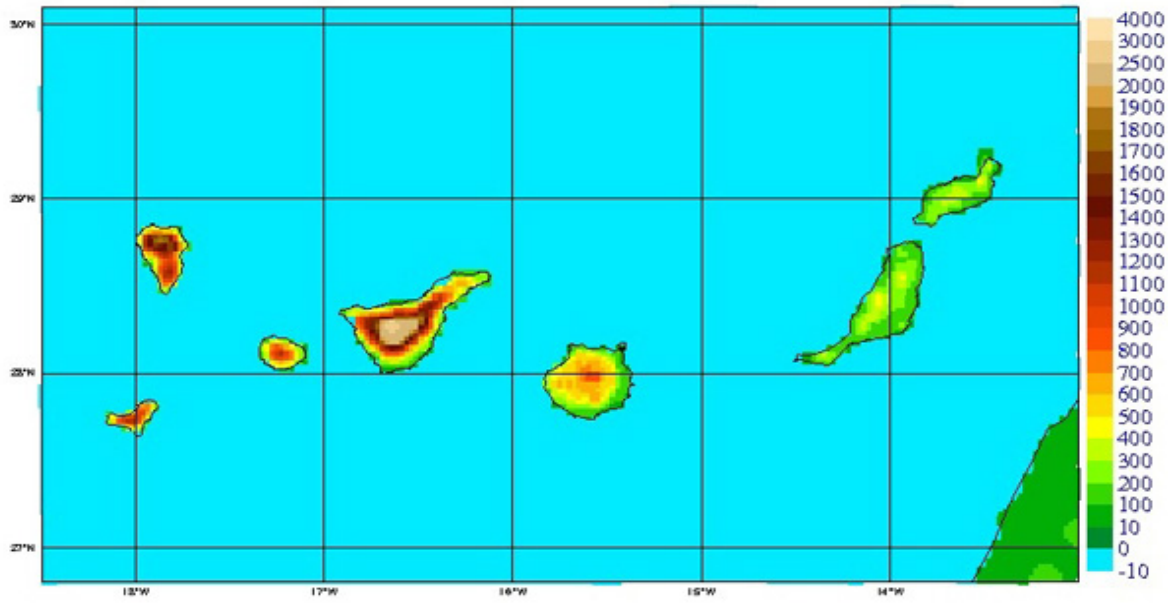
$$\phi = 0 \qquad \text{on } \Gamma_b$$

and, finally, the adjusted velocity field is obtained by: $\mathbf{u} = \mathbf{u_0} + \mathbf{P}^{-1} \nabla \phi$

HARMONIE Meteorological Model

Introduction

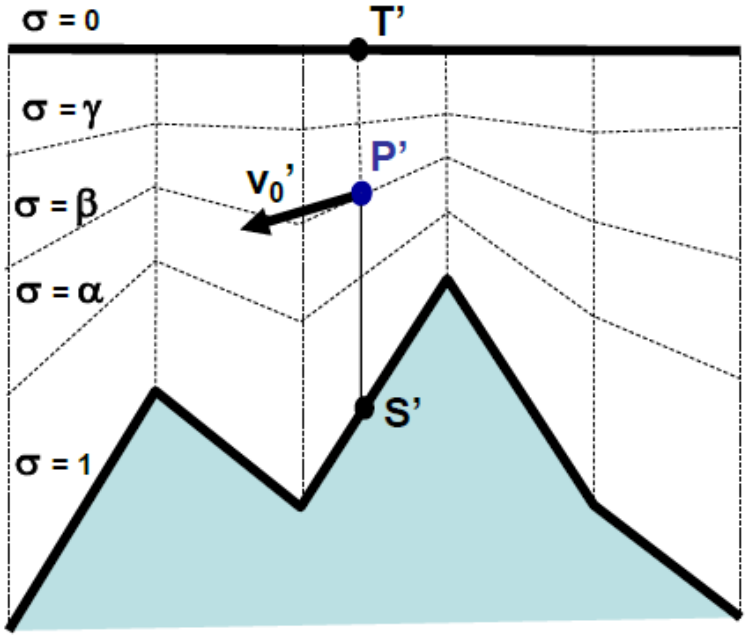
- Non-hydrostatic meteorological model based on HIRLAM
- From large scale to 1km or less scale (under developed)
- Different models in different scales
- Assimilation data system
- Run by AEMET daily



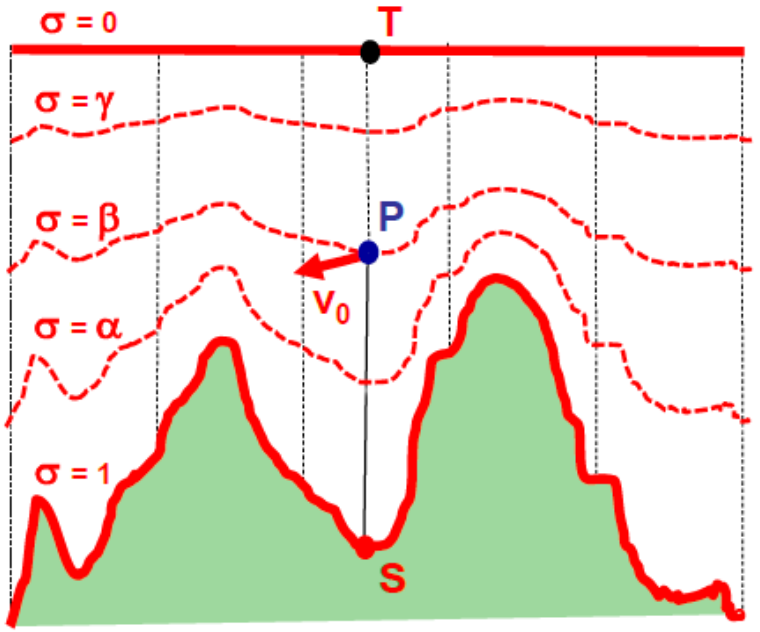
HARMONIE on Canary islands
(http://www.aemet.es/ca/idi/prediccion/prediccion_numerica)

HARMONIE Meteorological Model

Data interpolation in FE domain: Problems with terrain discretization



HARMONIE FD domain



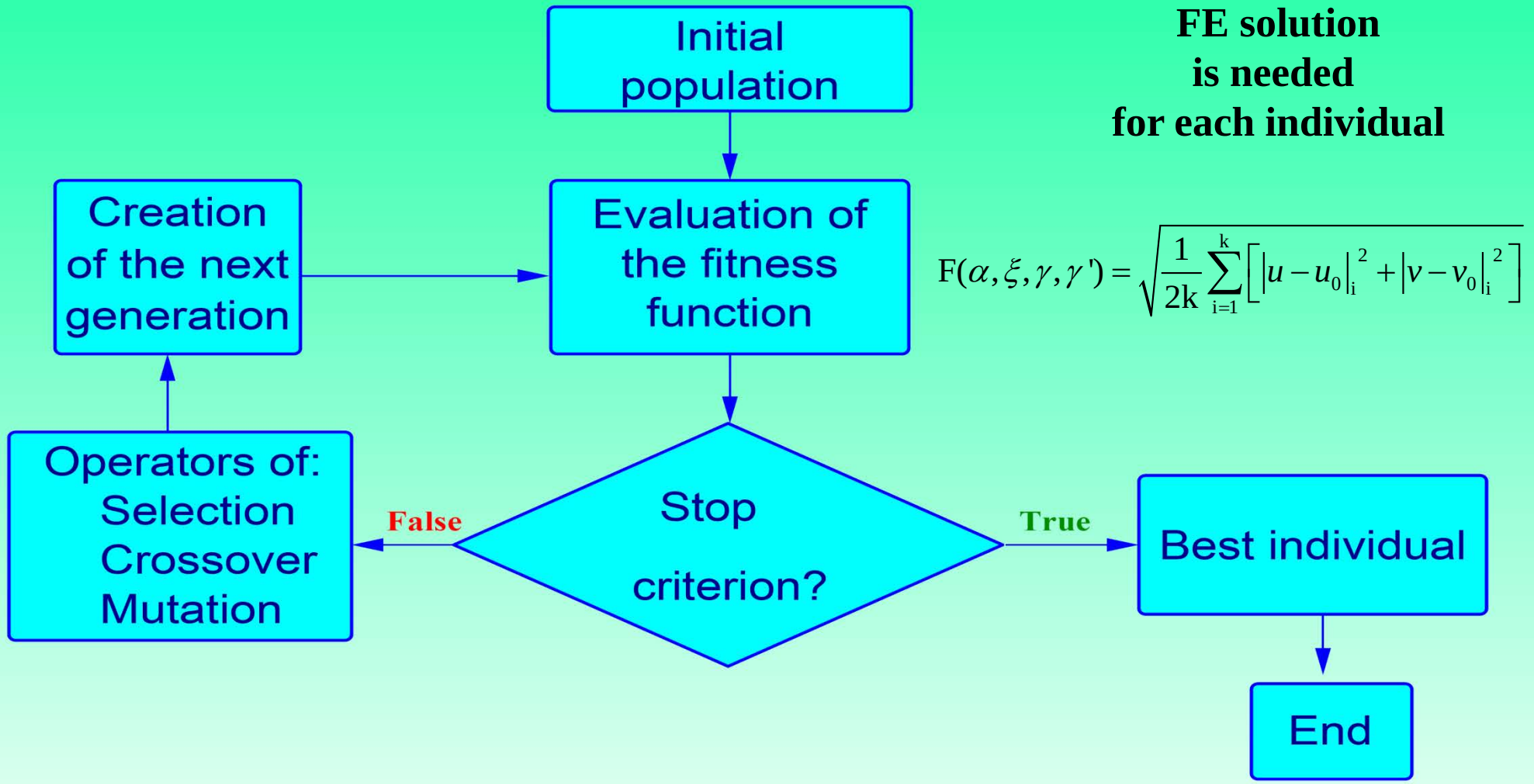
FE domain

Possible solutions for a suitable data interpolation in the FE domain:

- Use U10 and V10 supposing it is 10m over the FE terrain (used in this talk)
- Given a point of FE domain, find the closest one in HARMONIE domain grid
- Other possibilities can be considered

Estimation of Model Parameters

Genetic Algorithm



FE solution is needed for each individual

$$F(\alpha,\xi,\gamma,\gamma') = \sqrt{\frac{1}{2k}\sum_{i=1}^{k}\left[\left|u-u_0\right|_i^2+\left|v-v_0\right|_i^2\right]}$$

The Results

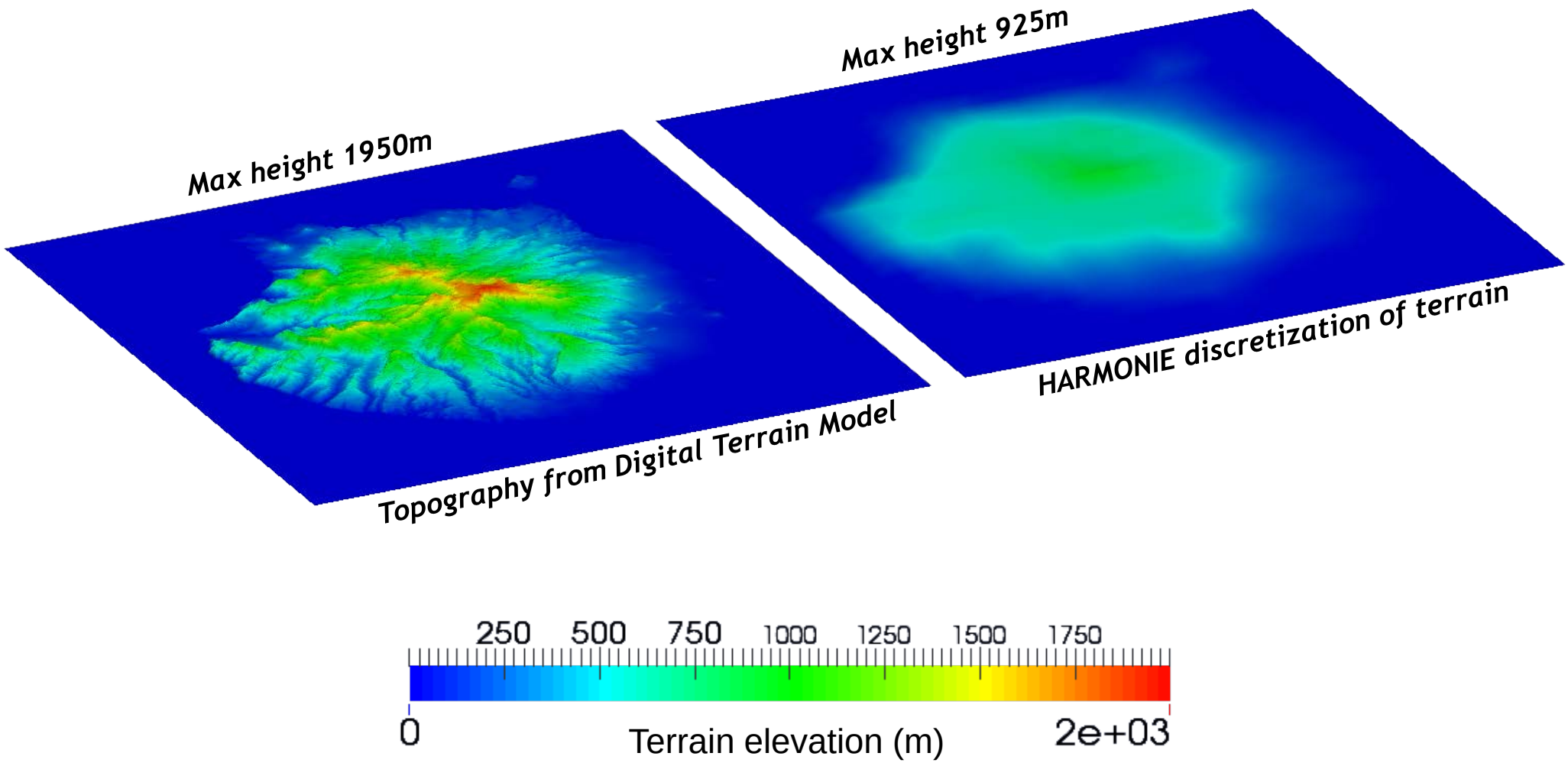
HARMONIE-FEM wind forecast

Results

- Wind field forecasting in Gran Canaria island
- HARMONIE data were provided by AEMET
- The main idea
  - Use HARMONIE data as reliable points
  - Adjust the FE wind field to HARMONIE data
  - By using genetic algorithms
- Applications to air quality modeling

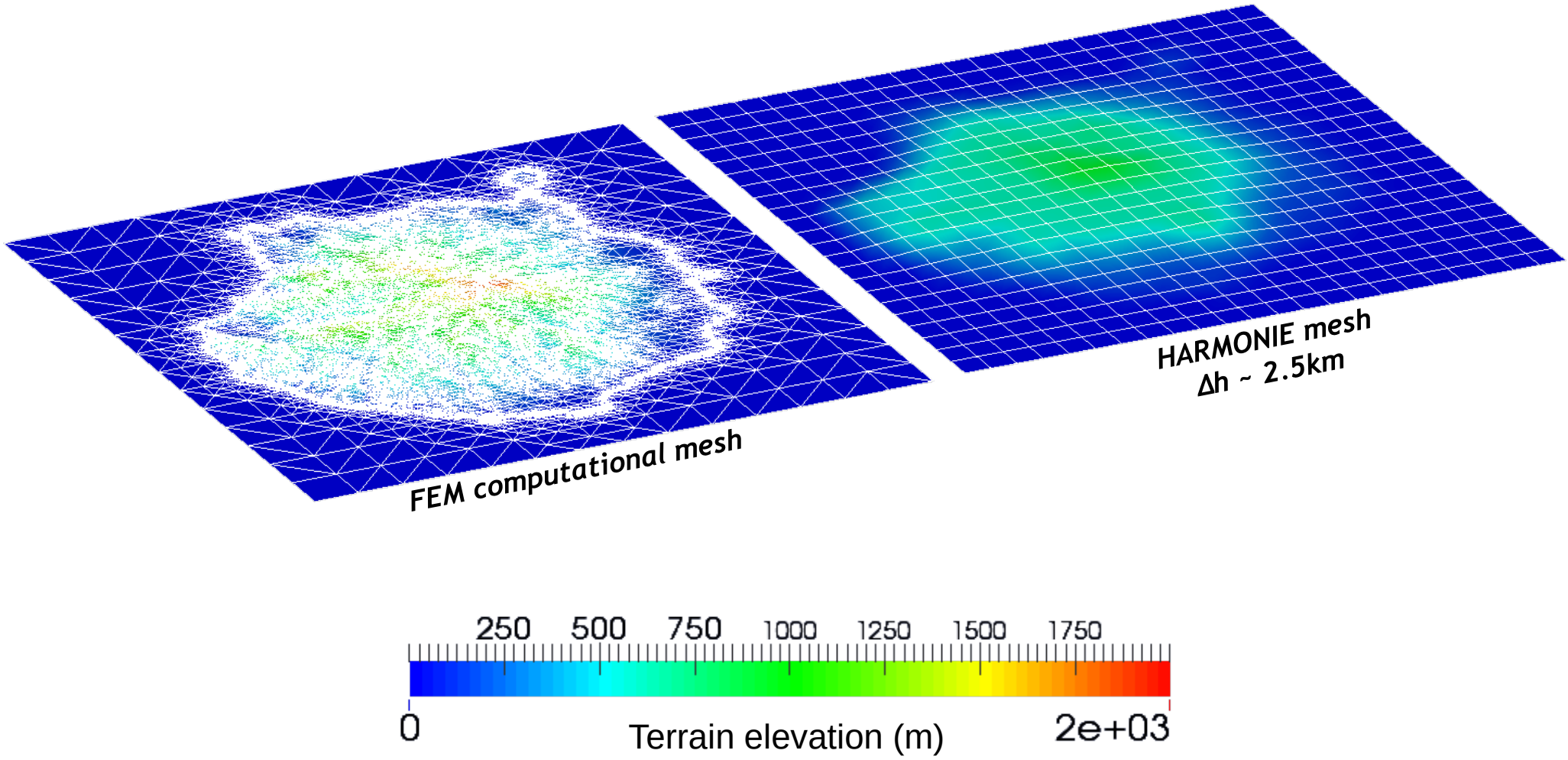
HARMONIE-FEM wind forecast

Terrain approximation



HARMONIE-FEM wind forecast

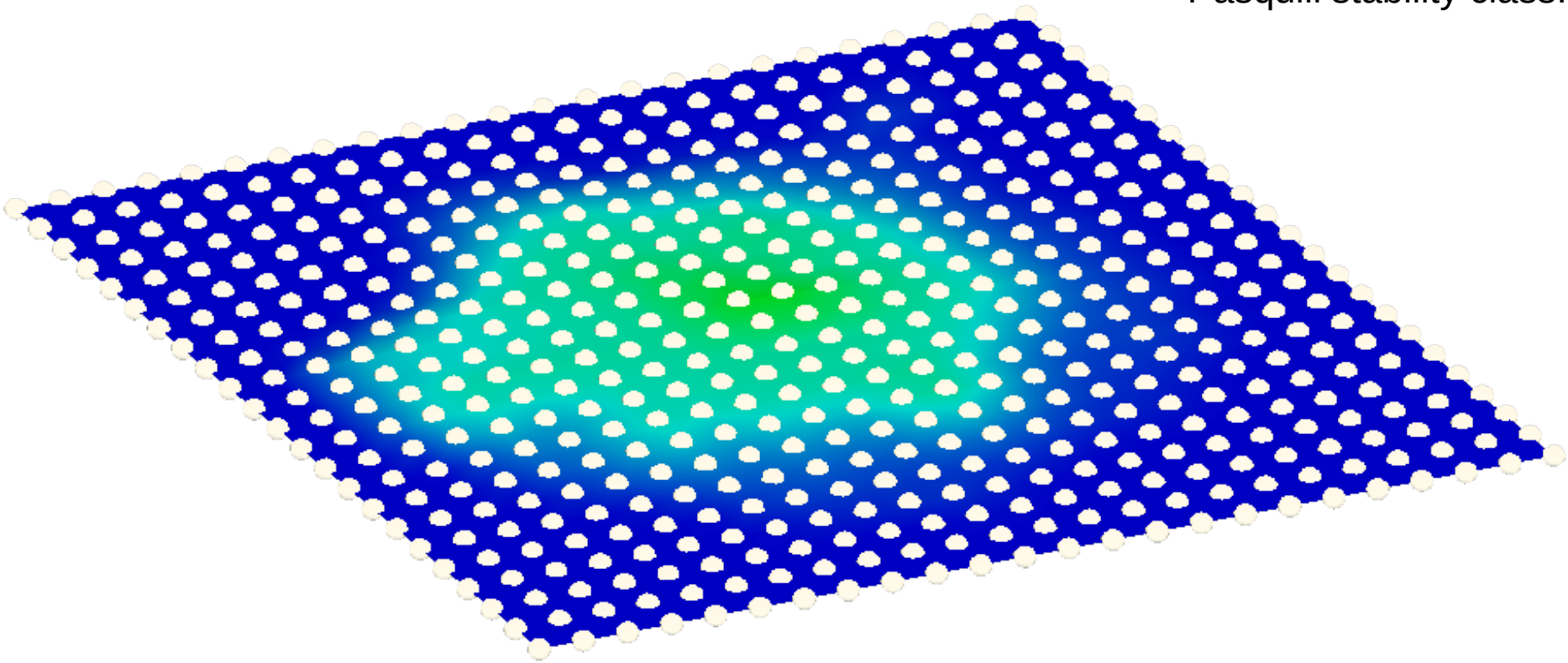
Spatial discretization



HARMONIE-FEM wind forecast

HARMONIE data

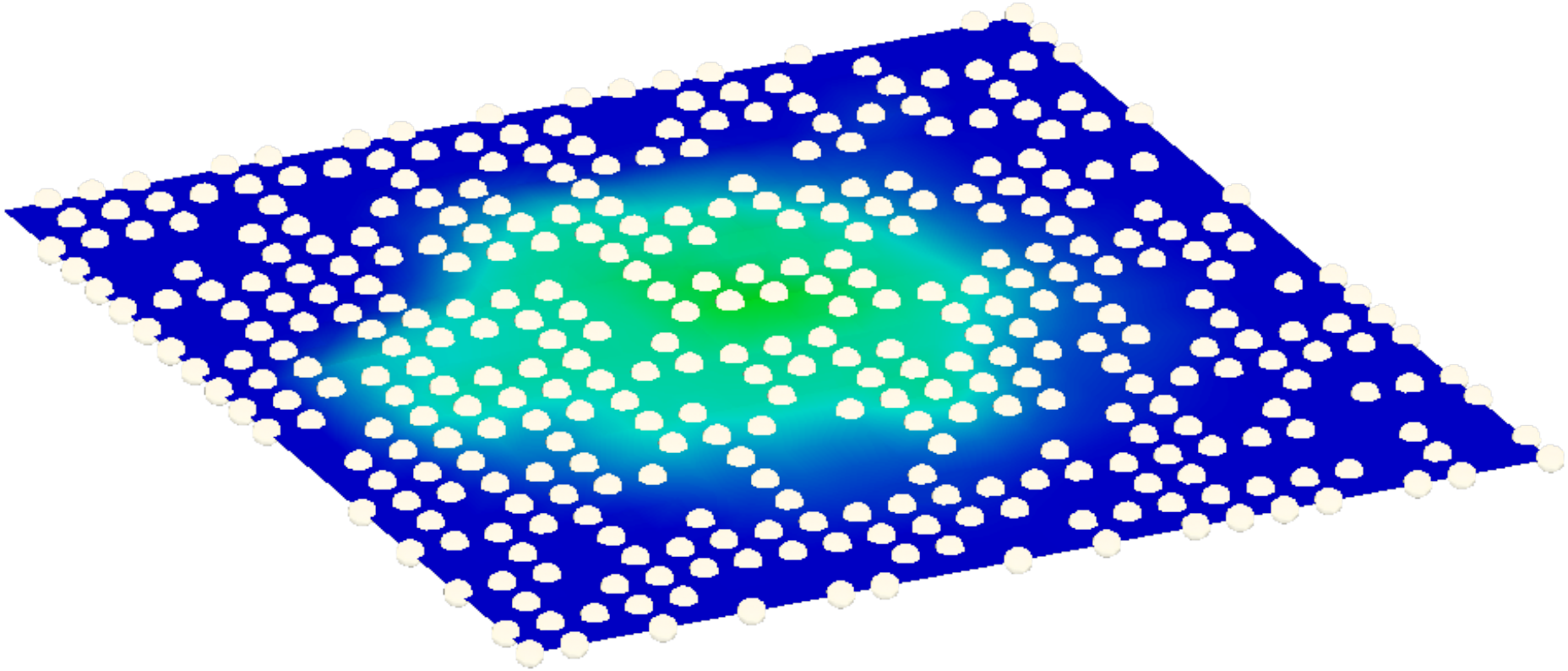
U_{10} V_{10} horizontal velocities
Geostrophic wind = (27.3, -3.9)
Pasquill stability class: Stable



HARMONIE U_{10} V_{10} data points

HARMONIE-FEM wind forecast

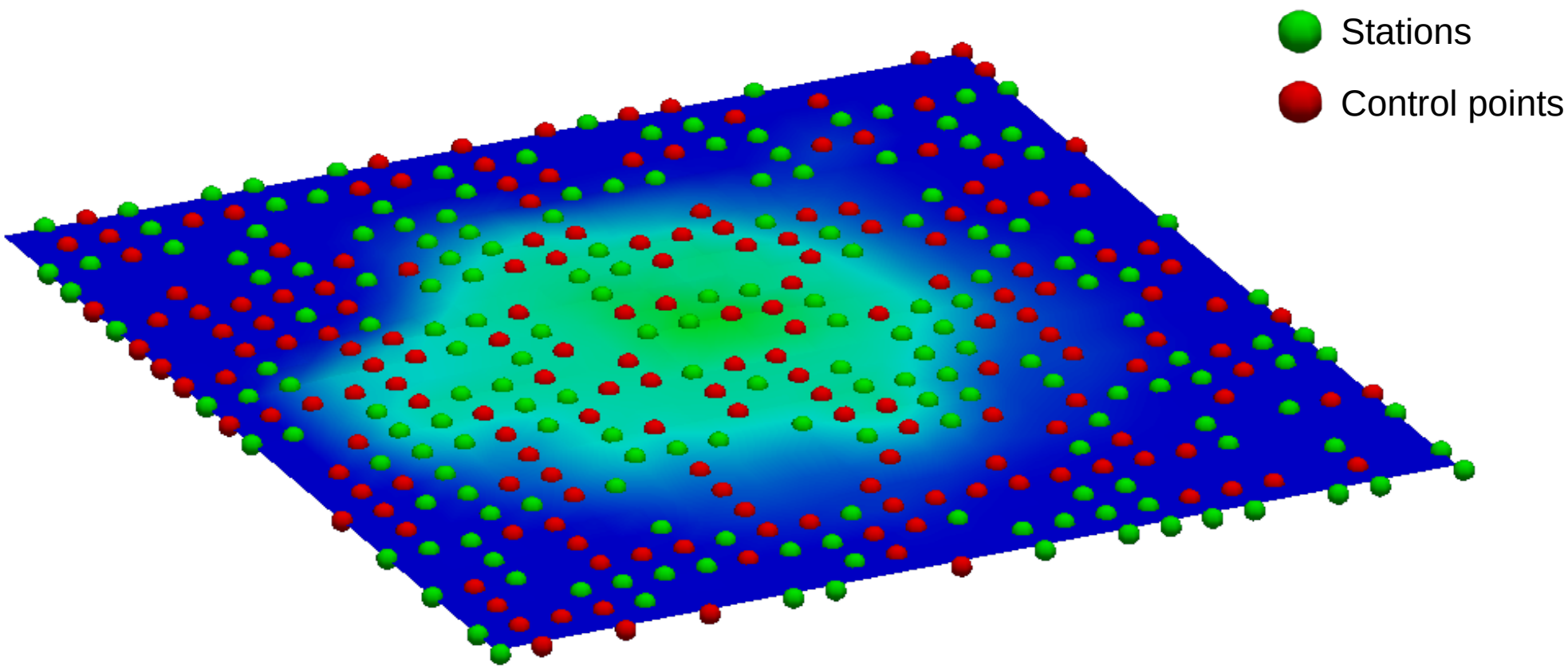
Stations election



Used data (2/3 of total)

HARMONIE-FEM wind forecast

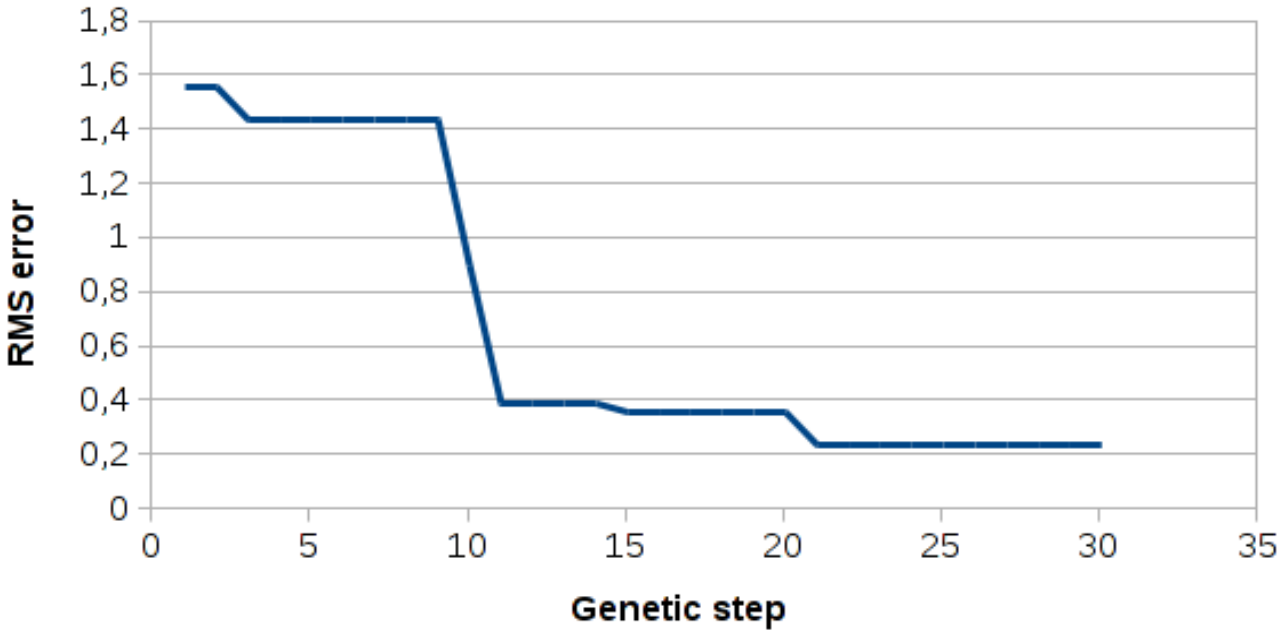
Stations election



Stations (1/3) and control points (1/3)

HARMONIE-FEM wind forecast

Genetic algorithm results

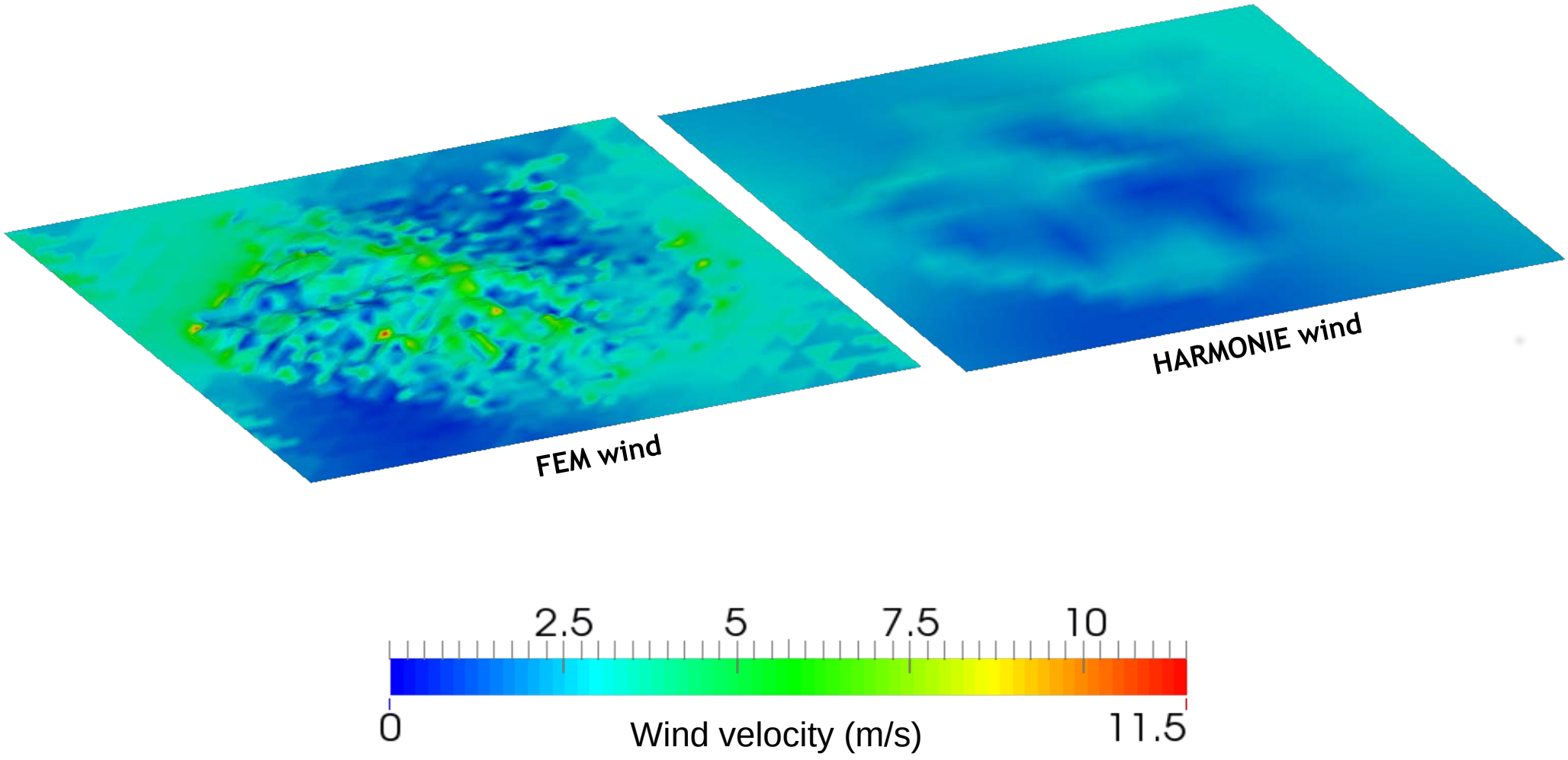


Optimal parameter values

Alpha = 2.302731
Epsilon = 0.938761
Gamma = 0.279533
Gamma‘ = 0.432957

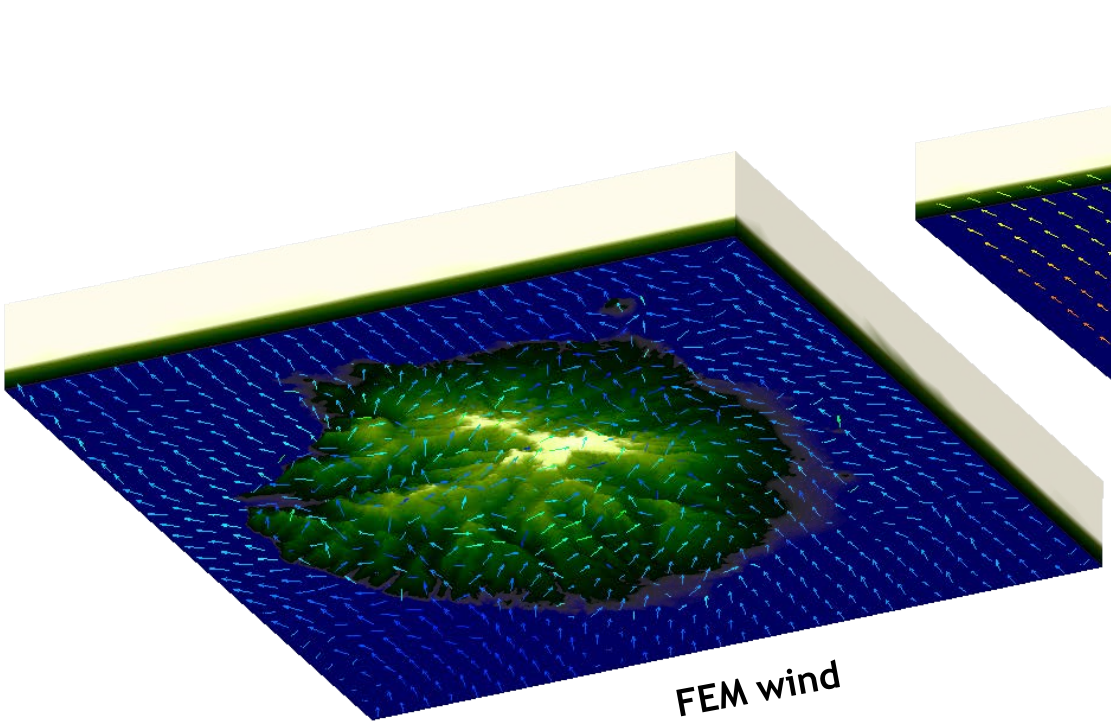
HARMONIE-FEM wind forecast

Wind magnitude at 10m over terrain

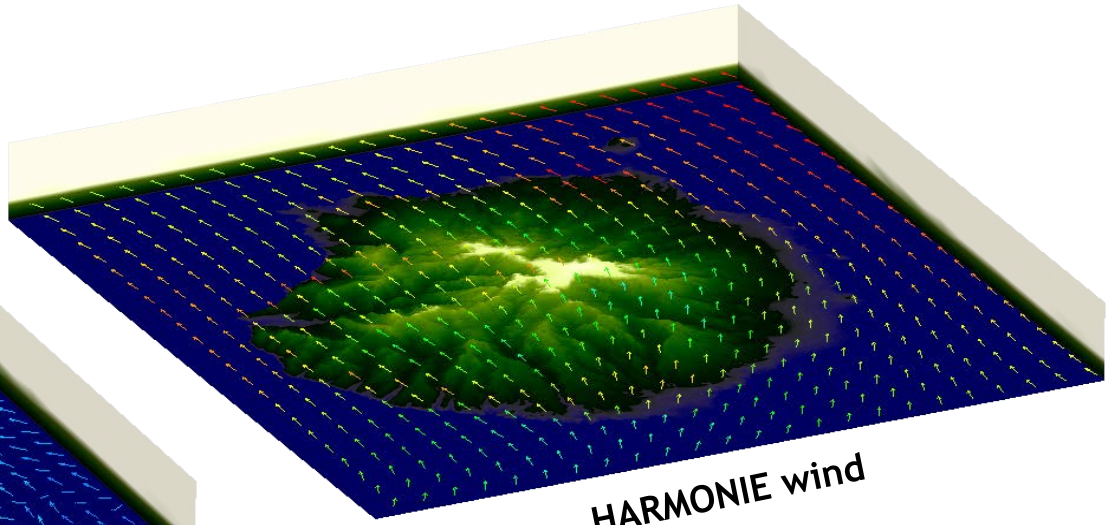


HARMONIE-FEM wind forecast

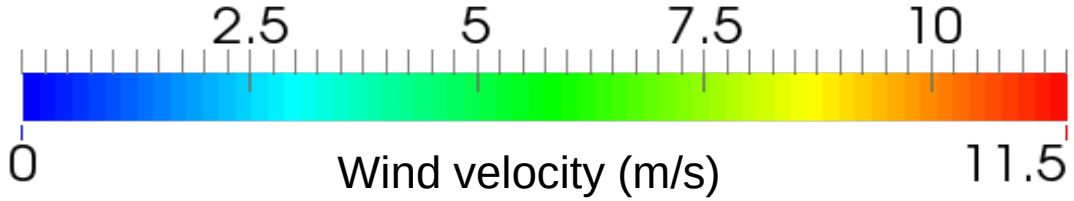
Wind field at 10m over terrain



FEM wind

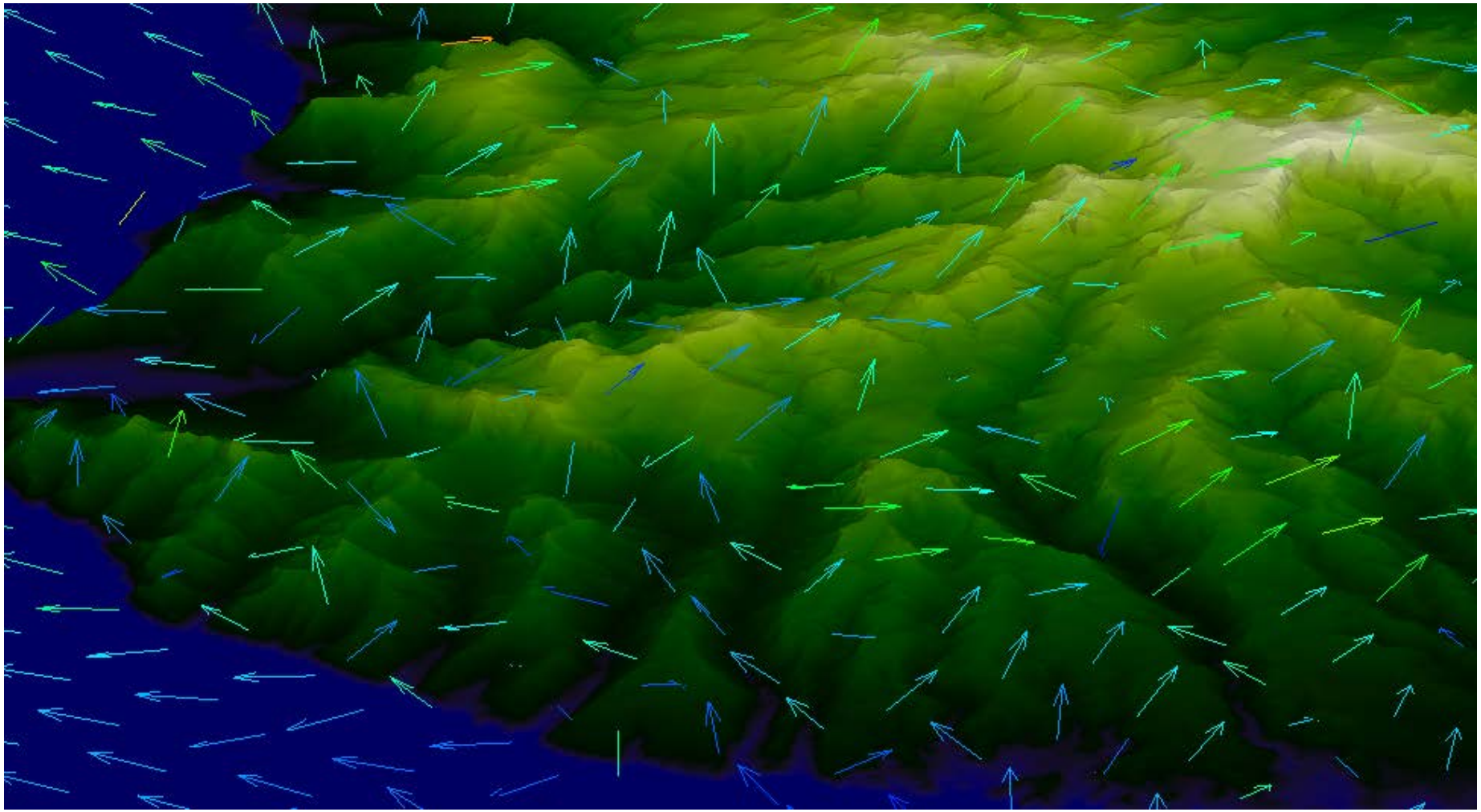


HARMONIE wind



HARMONIE-FEM wind forecast

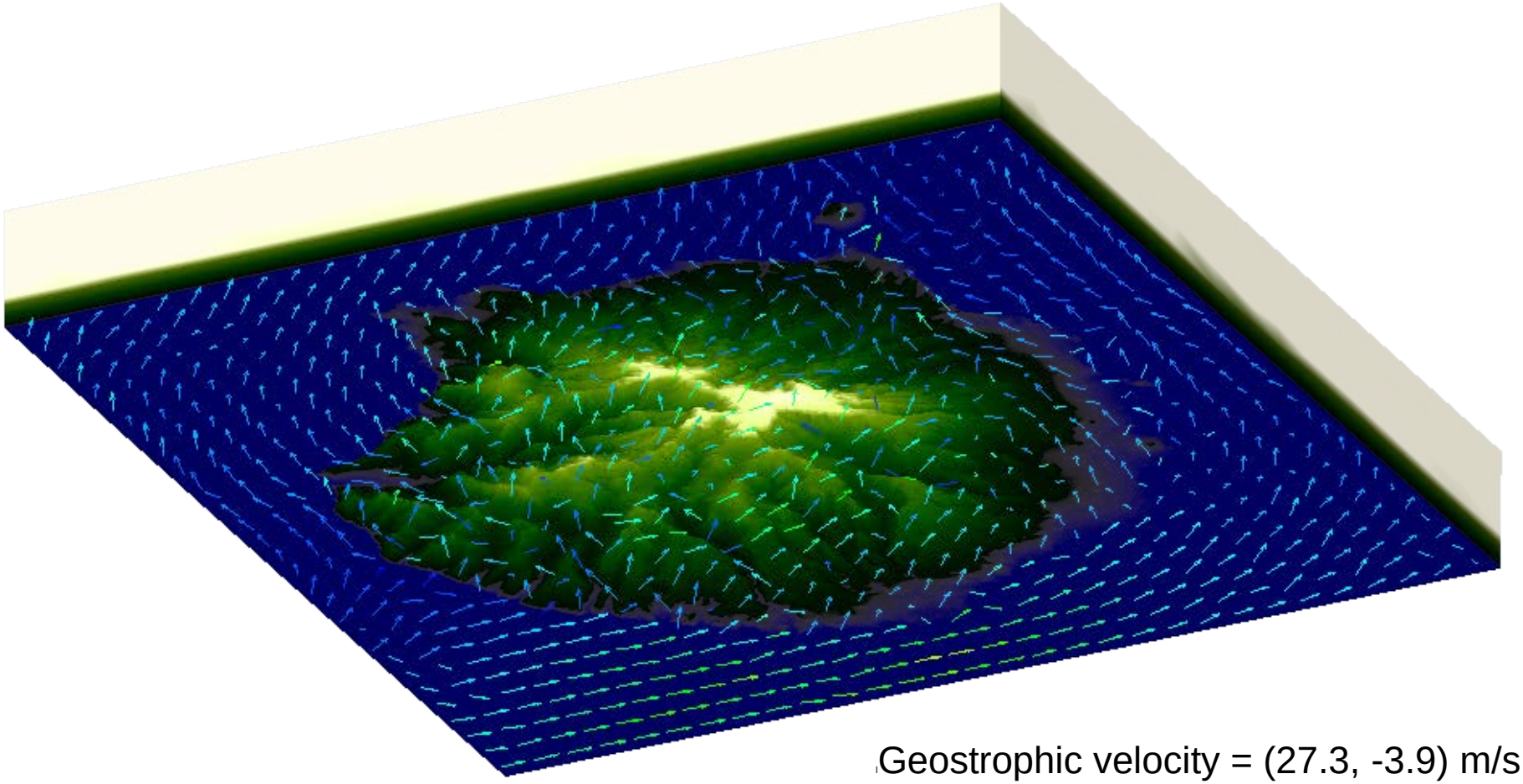
Wind field at 10m over terrain



Zoom

HARMONIE-FEM wind forecast

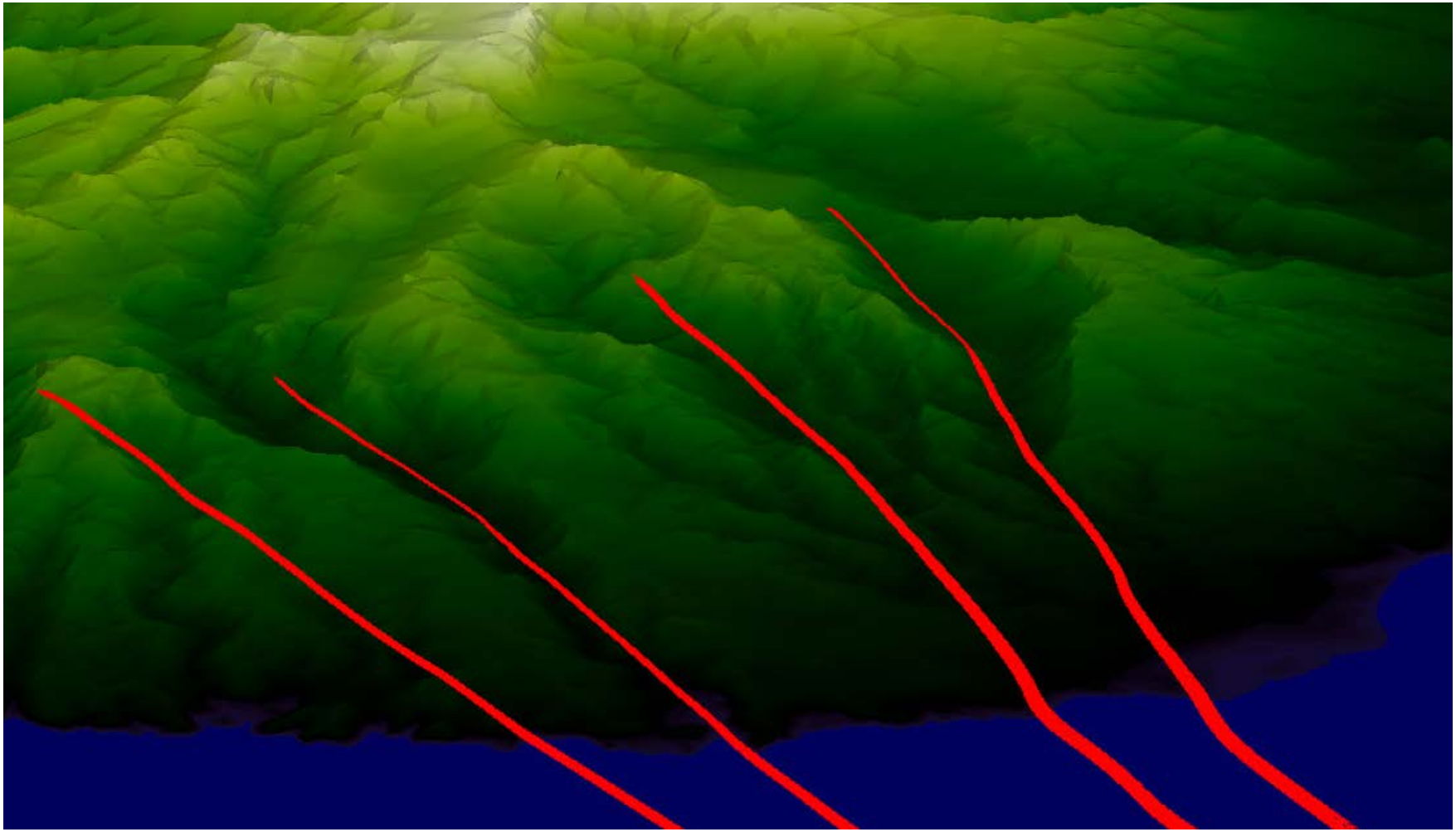
Wind field at 100m over terrain



Geostrophic velocity = (27.3, -3.9) m/s

HARMONIE-FEM wind forecast

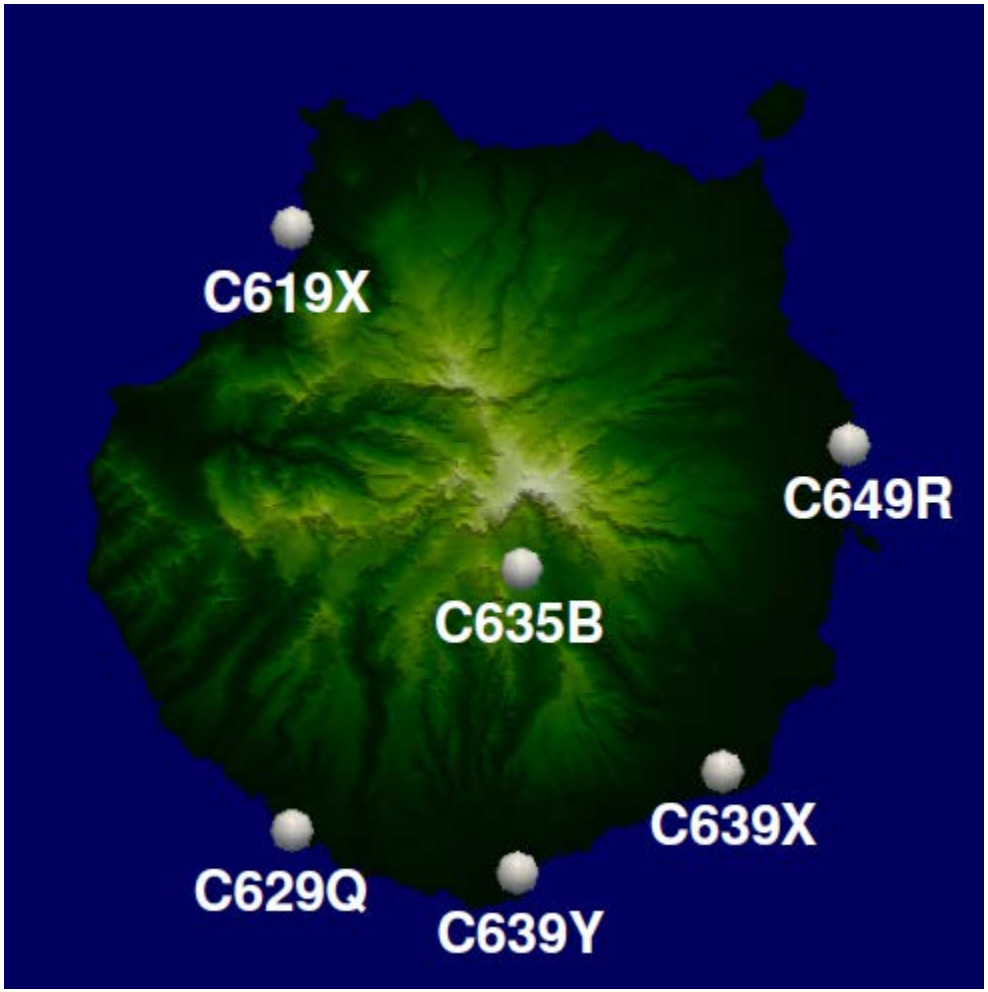
Wind field over terrain (detail of streamlines)



Zoom

HARMONIE-FEM wind forecast

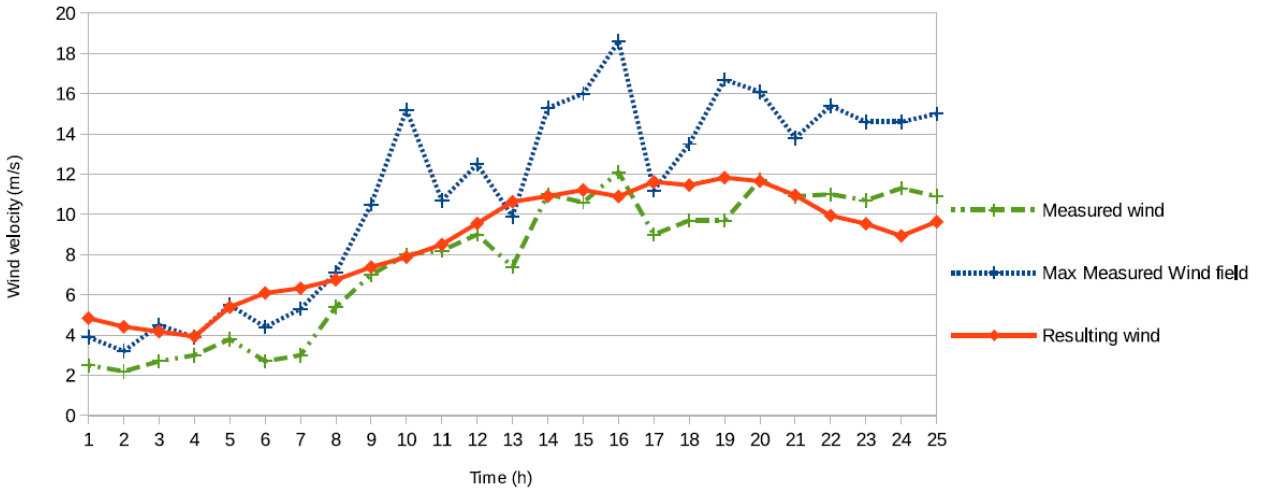
Forecast wind validation (location of measurement stations)



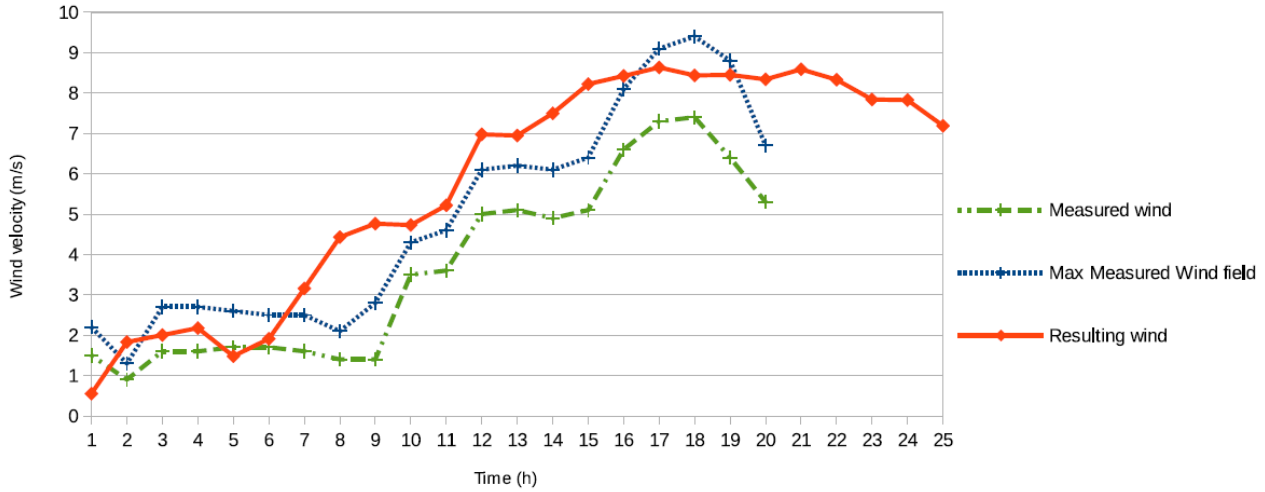
HARMONIE-FEM wind forecast

Forecast wind along a day

C619X measurement station



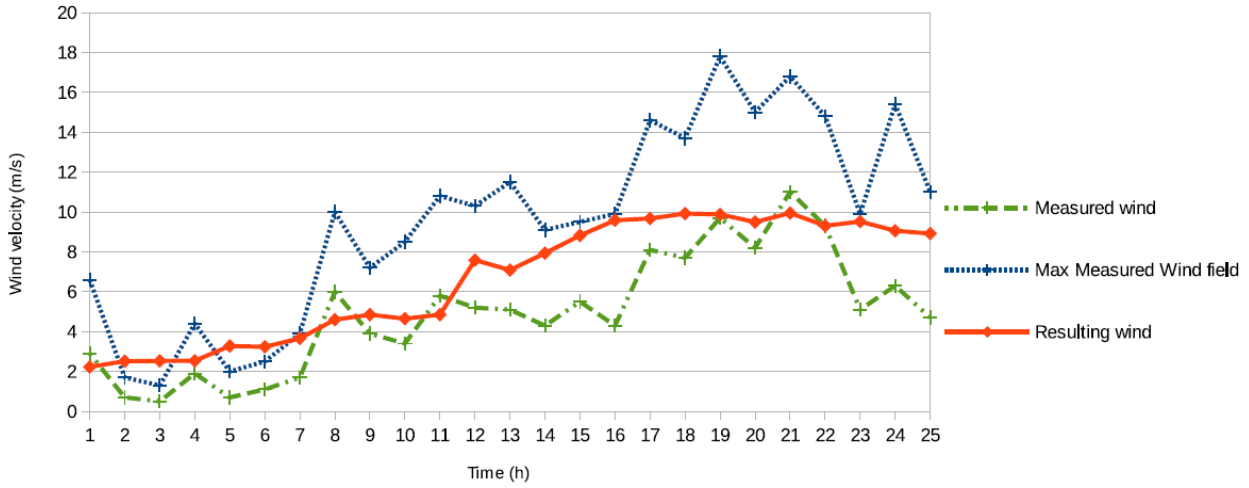
C629Q measurement station



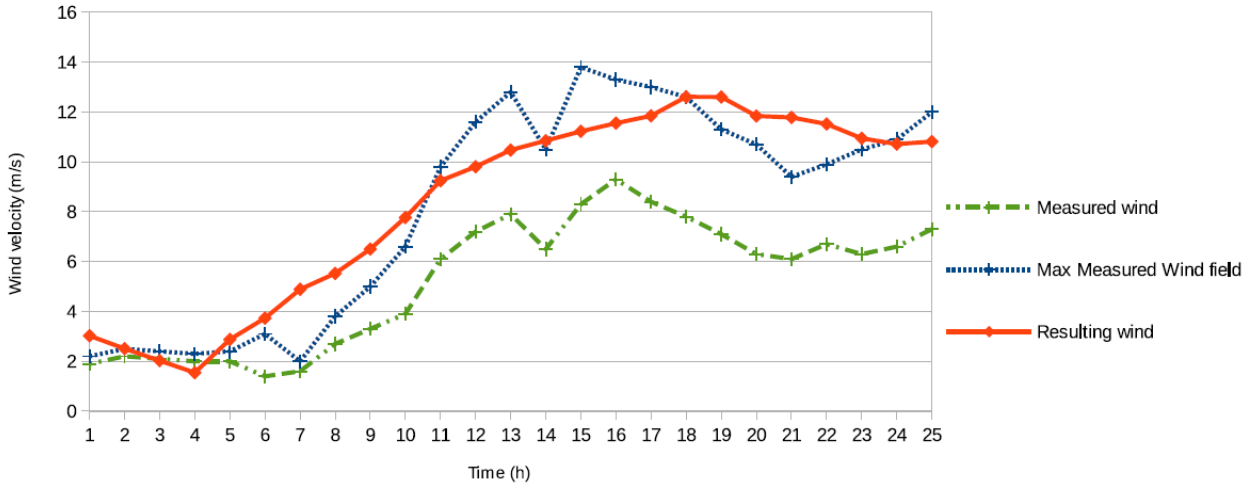
HARMONIE-FEM wind forecast

Forecast wind along a day

C635B measurement station



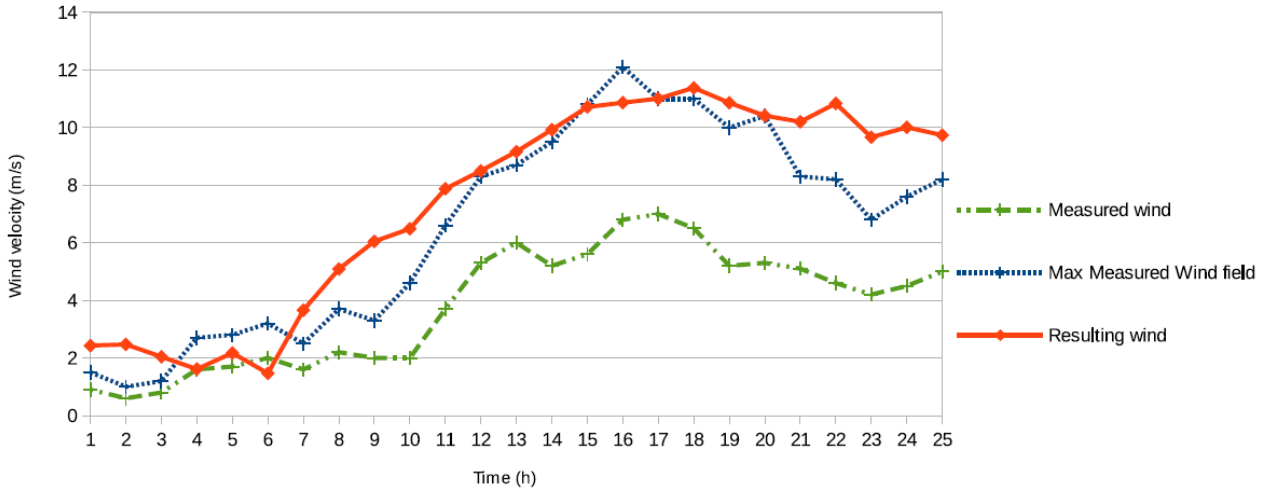
C639X measurement station



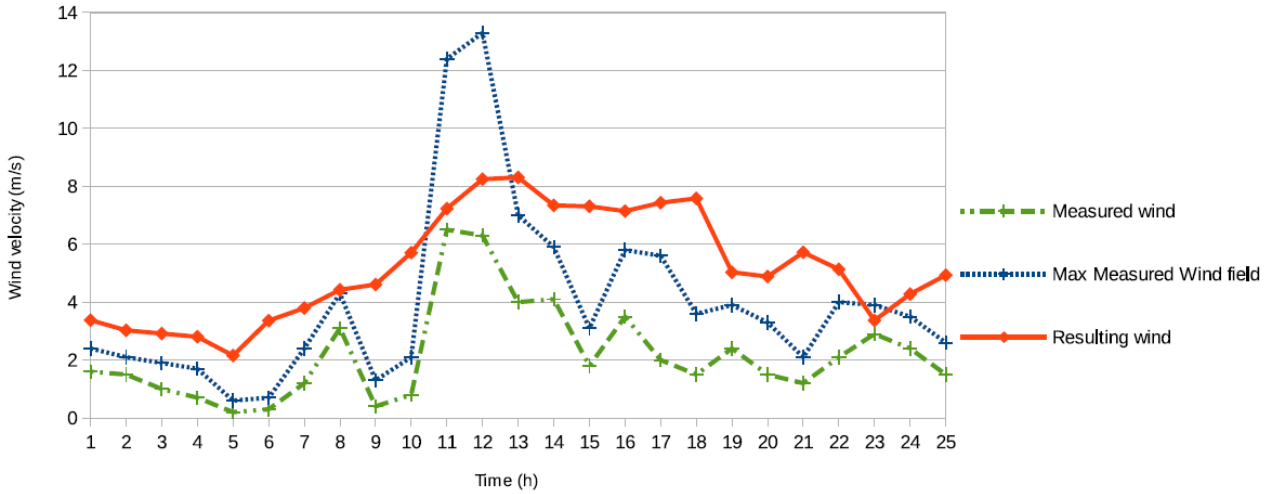
HARMONIE-FEM wind forecast

Forecast wind along a day

C639Y measurement station

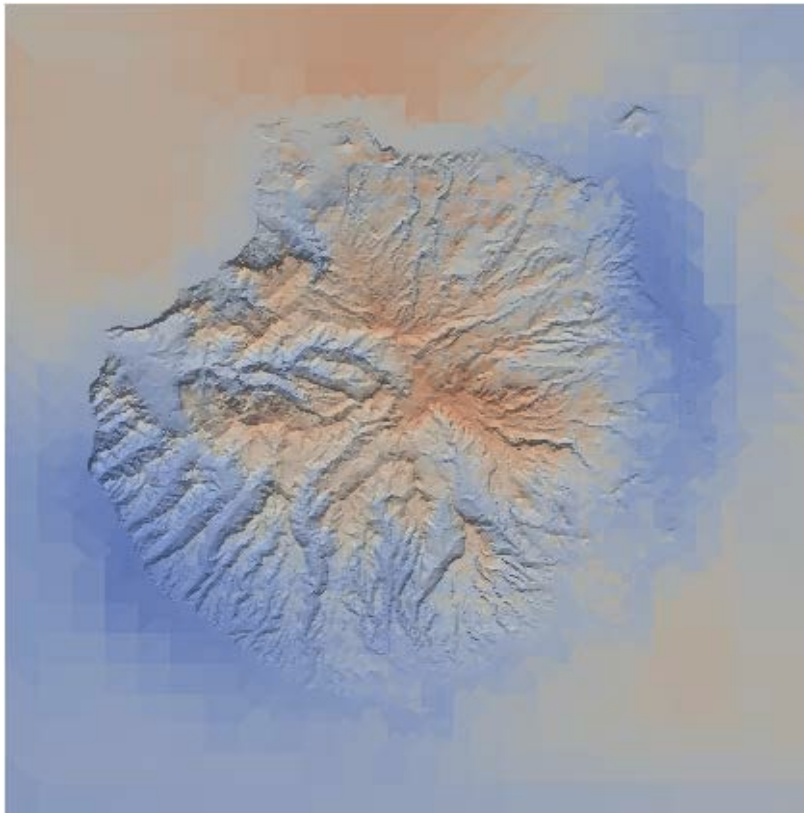


C649R measurement station

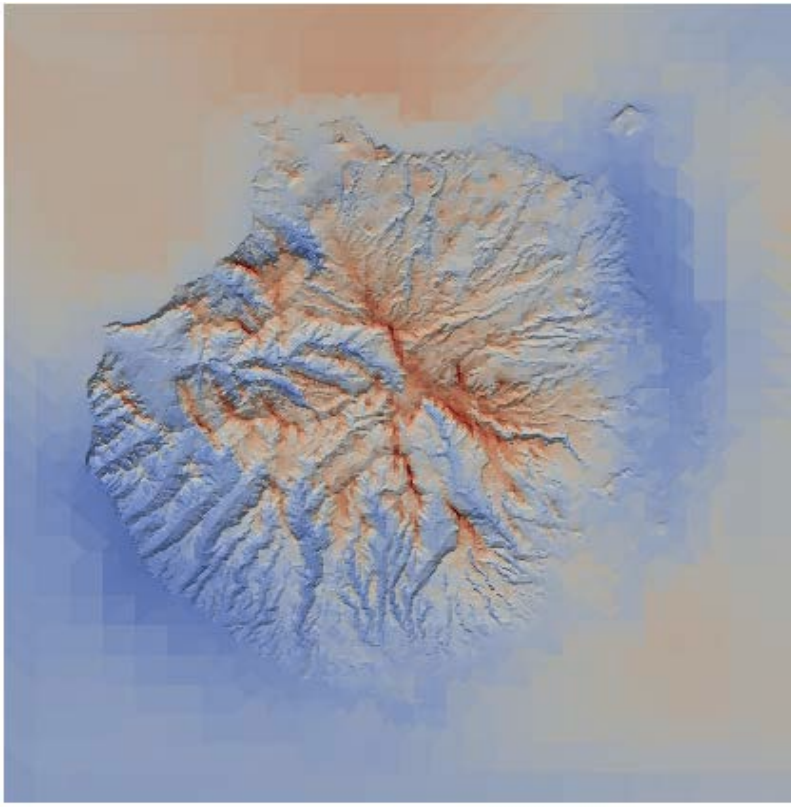


Velocity Module - 23/12/2009 - 18:00 h

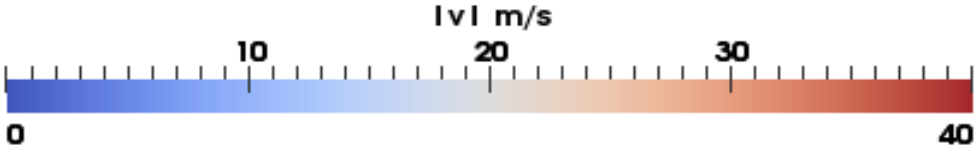
Wind on the terrain surface



Interpolated field from HARMONIE

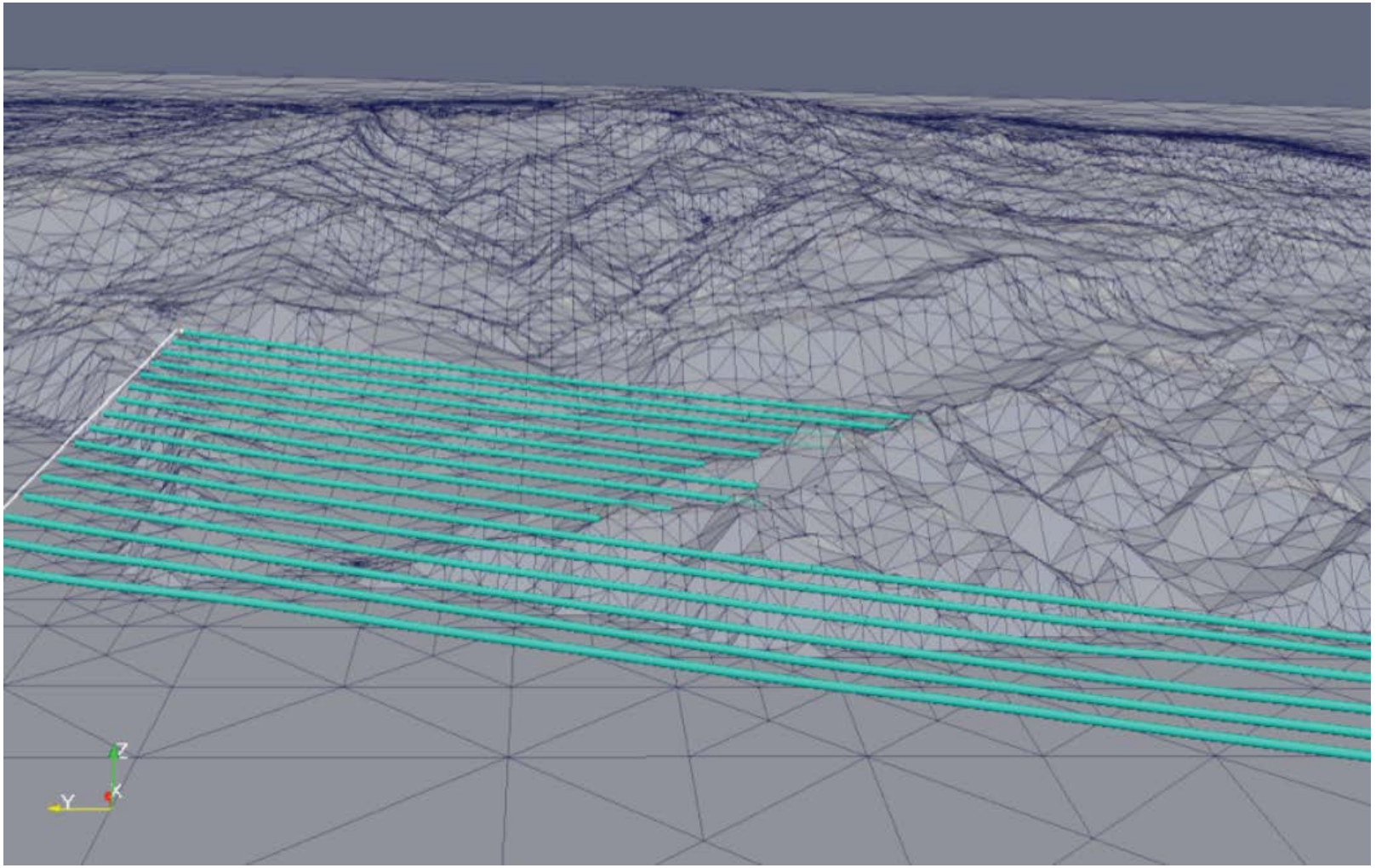


Resulting field with the mass consistent model



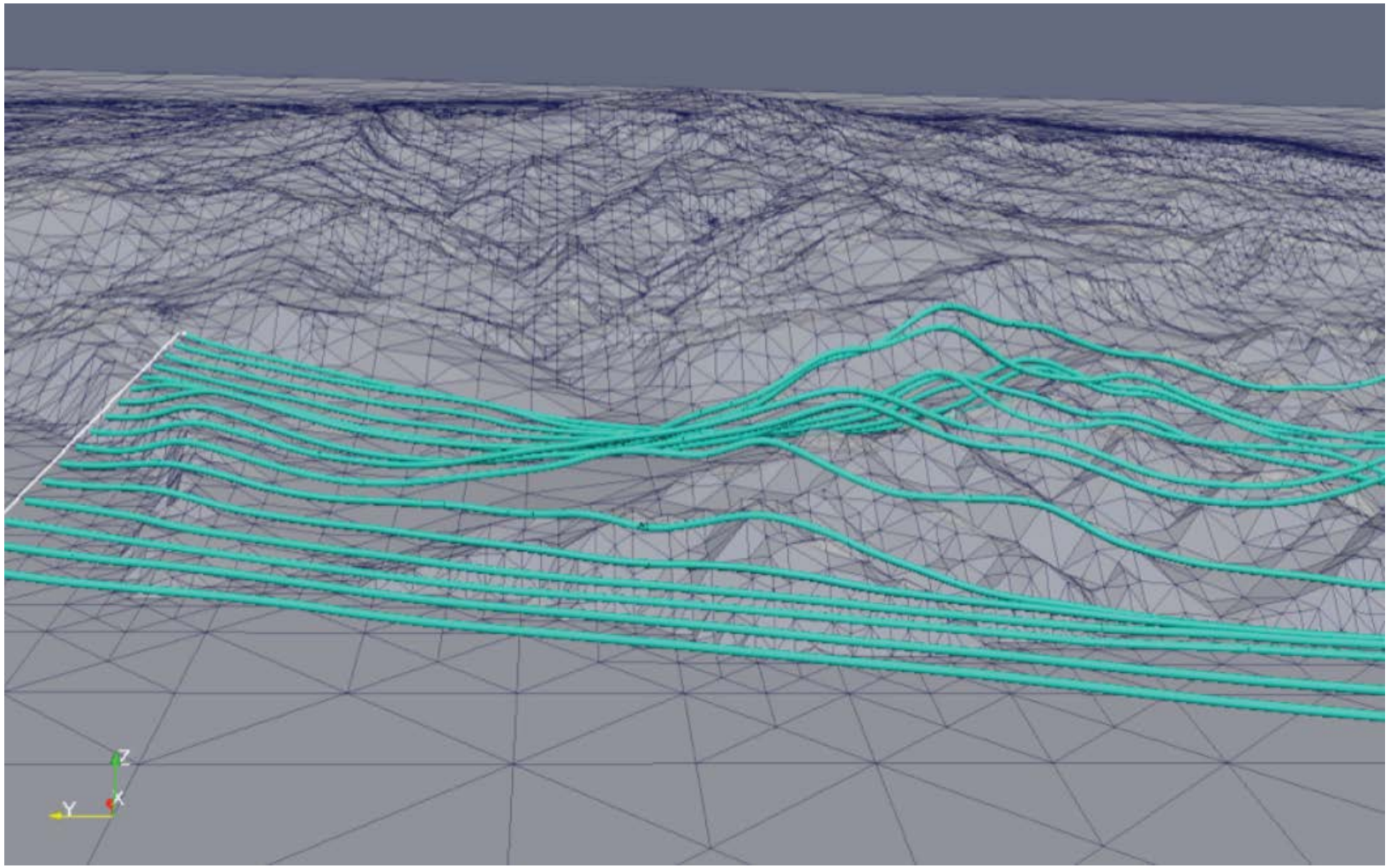
Mass Consistent Wind Field Simulation

Streamlines of the interpolated field in Gran Canaria Island



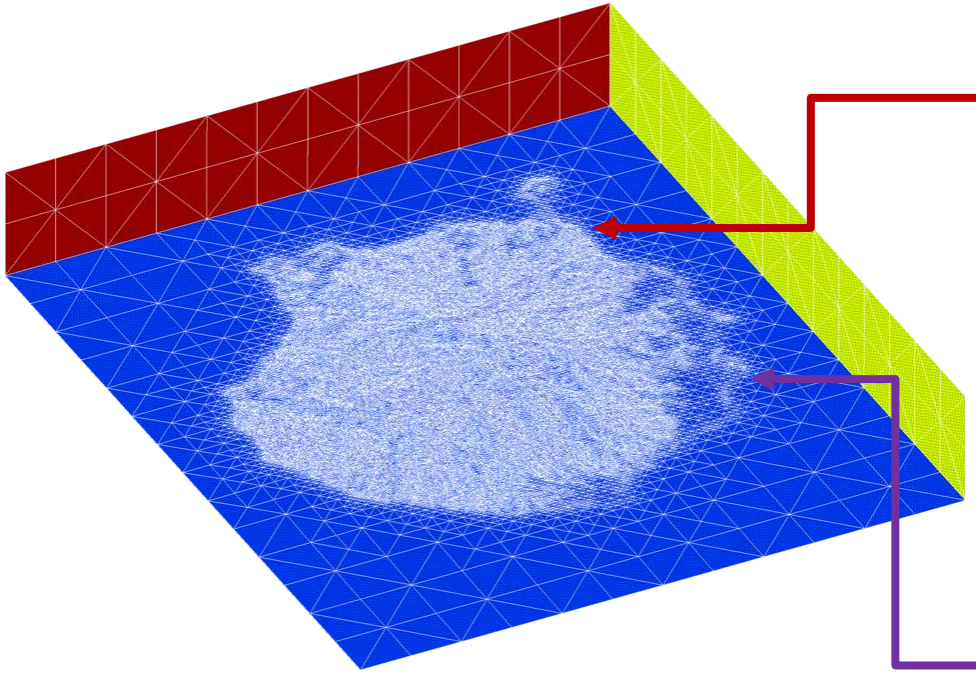
Mass Consistent Wind Field Simulation

Streamlines of the resulting field in Gran Canaria Island

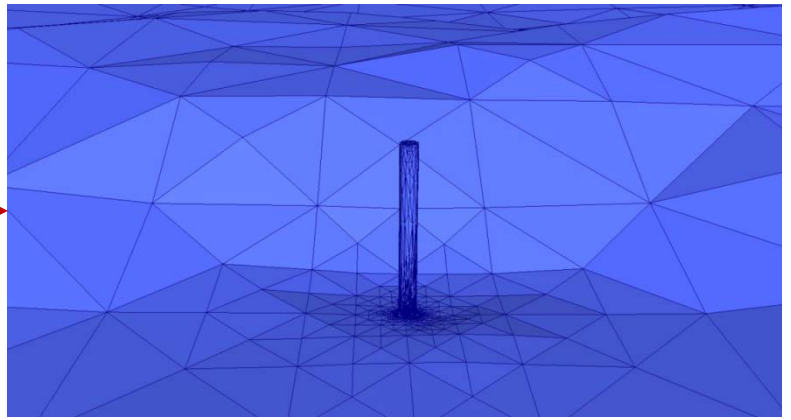


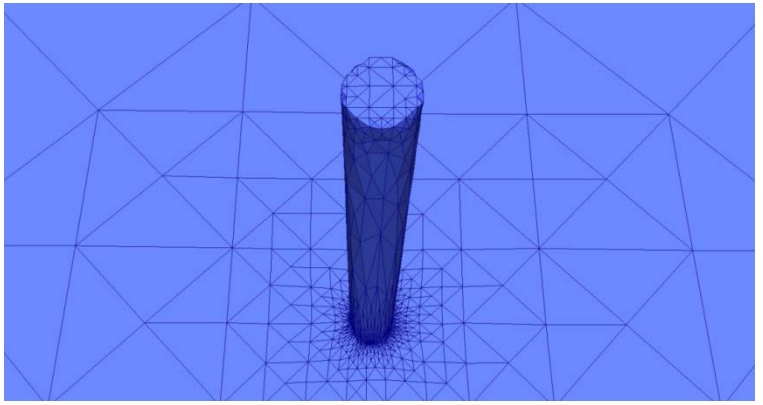
Wind Field for Air Quality Simulation

Gran Canaria: Stacks of Jinámar and Juan Grande



Gran Canaria Island

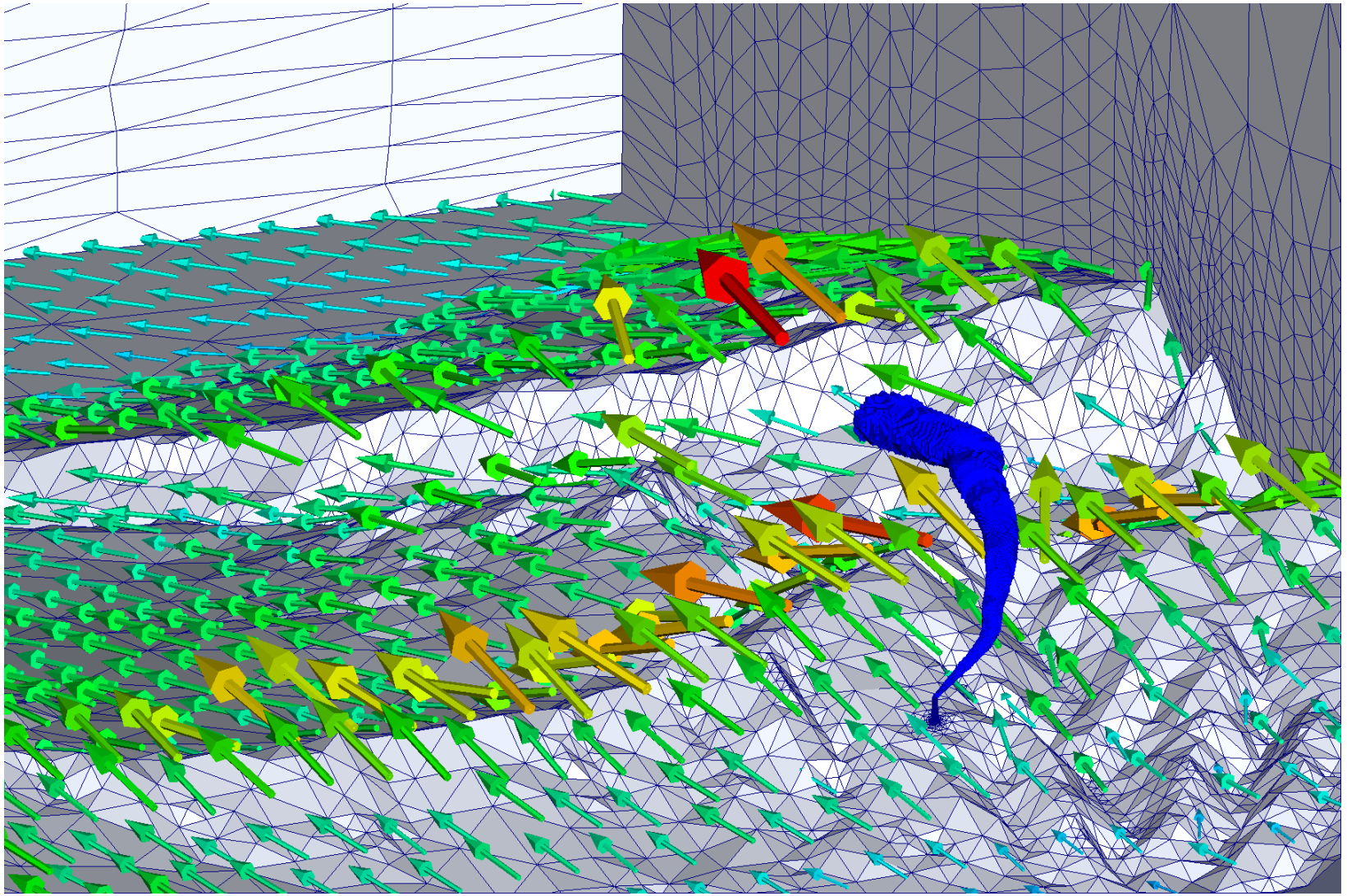




Wind Field for Air Quality Simulation

Mesh adaptation to geometry and gaussian plume

SIANI

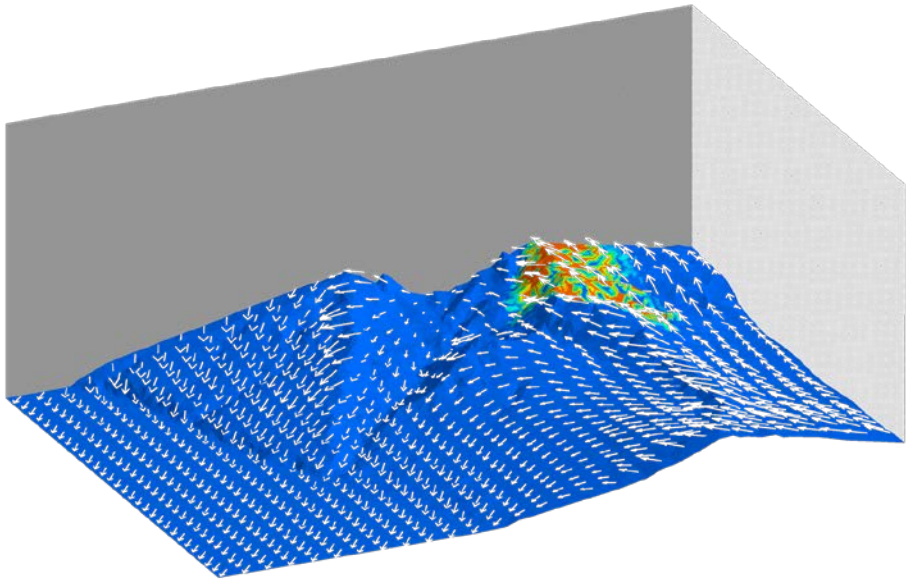


Wind Field for Air Quality Simulation

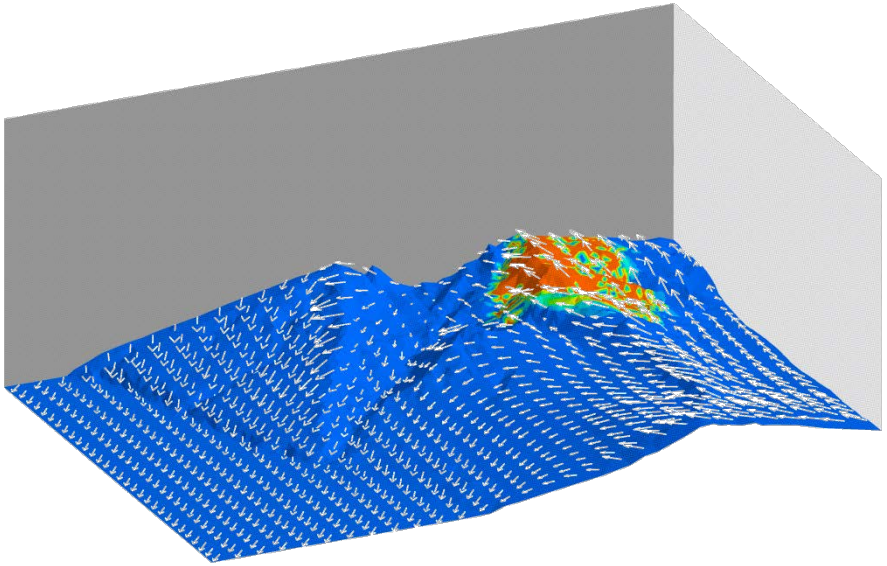
Pollutant immission

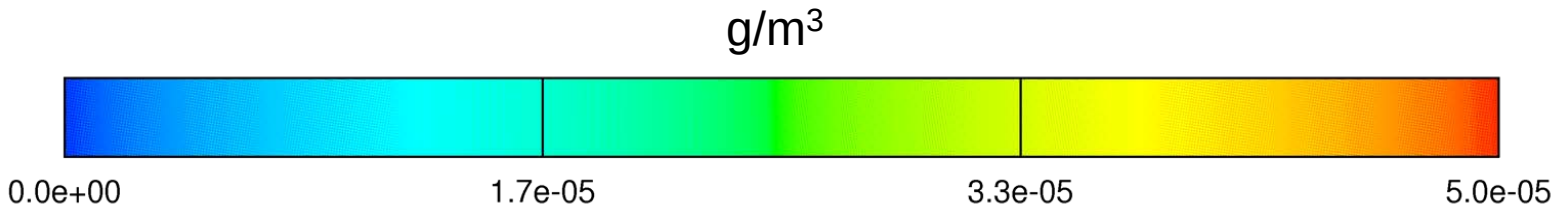
Immission concentration distribution after 1000 seconds

Primary (SO_2)



Secondary (SO_4)

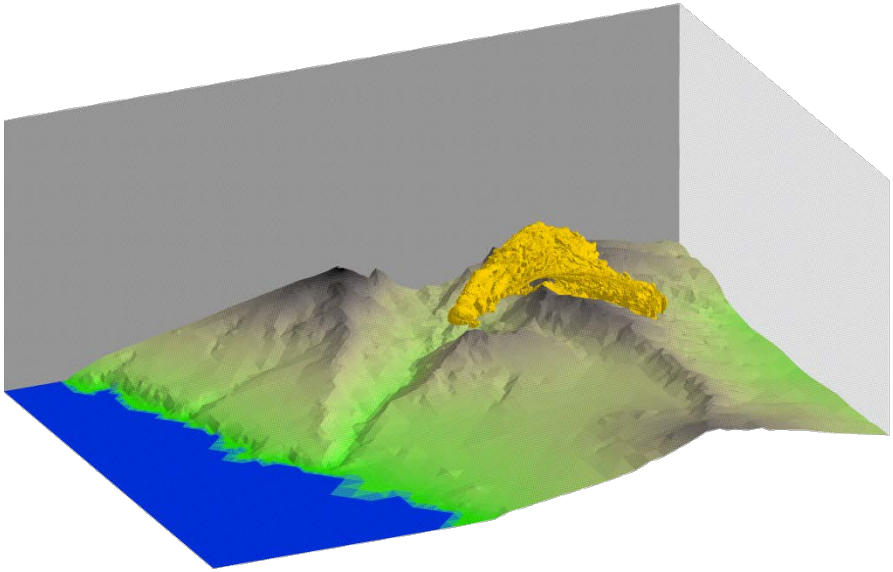




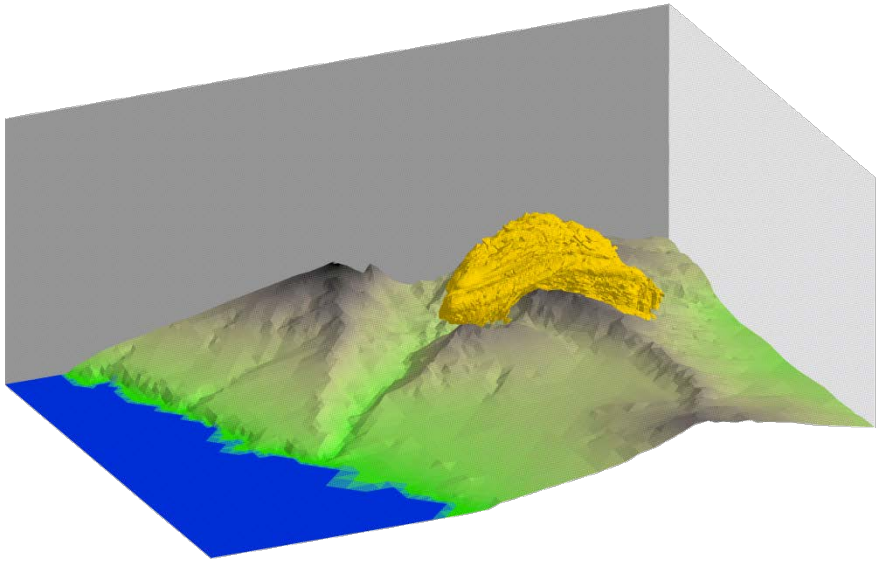
Wind Field for Air Quality Simulation

Pollutant isosurface

Isosurface of 50 μg/m^3 after 1000 seconds



Primary (SO_2)



Secondary (SO_4)

Final Comments

- The proposed approach is suitable for forecasting the wind field in complex terrain
- Genetic algorithms are crucial to solve the problem
- Wind fields can be used in other areas of interest in earth sciences e.g. Air Quality

Three-dimensional simulation of wind fields and air pollution over complex terrain

A. Oliver[(1)], E. Rodríguez[(1)], J. Ramírez[(1)], J.I. López[(1)], M. Brovka[(1)], J.M. Escobar[(1)], J.M. Cascón[(2)], F. Díaz[(1)], G.V. Socorro[(1)], G. Montero[(1)] and R. Montenegro[(1)*]

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

[(2)] Department of Economics and History of Economics, University of Salamanca, Spain

CEID Annual Seminar 2014, LUT, Lappeenranta University of Technology,

27th May, 2014, Lappeenranta, Finland

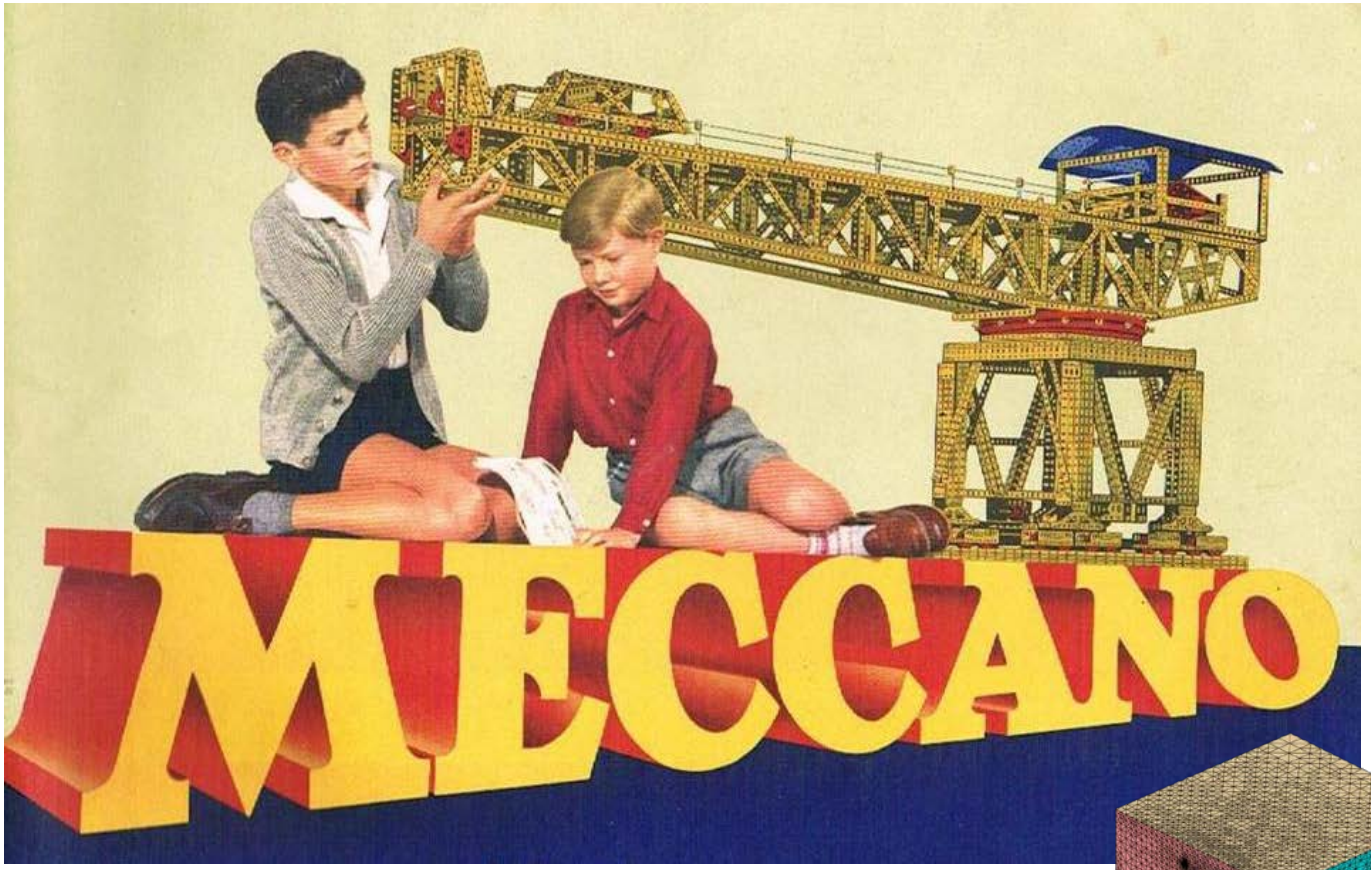
MINECO y FEDER Project: CGL2011-29396-C03-00

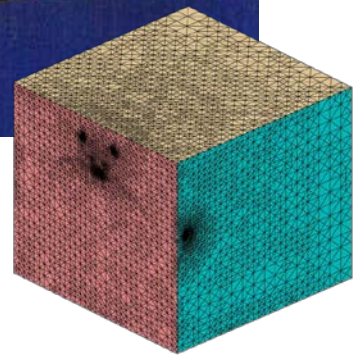
CONACYT-SENER Project, Fondo Sectorial, contract: 163723

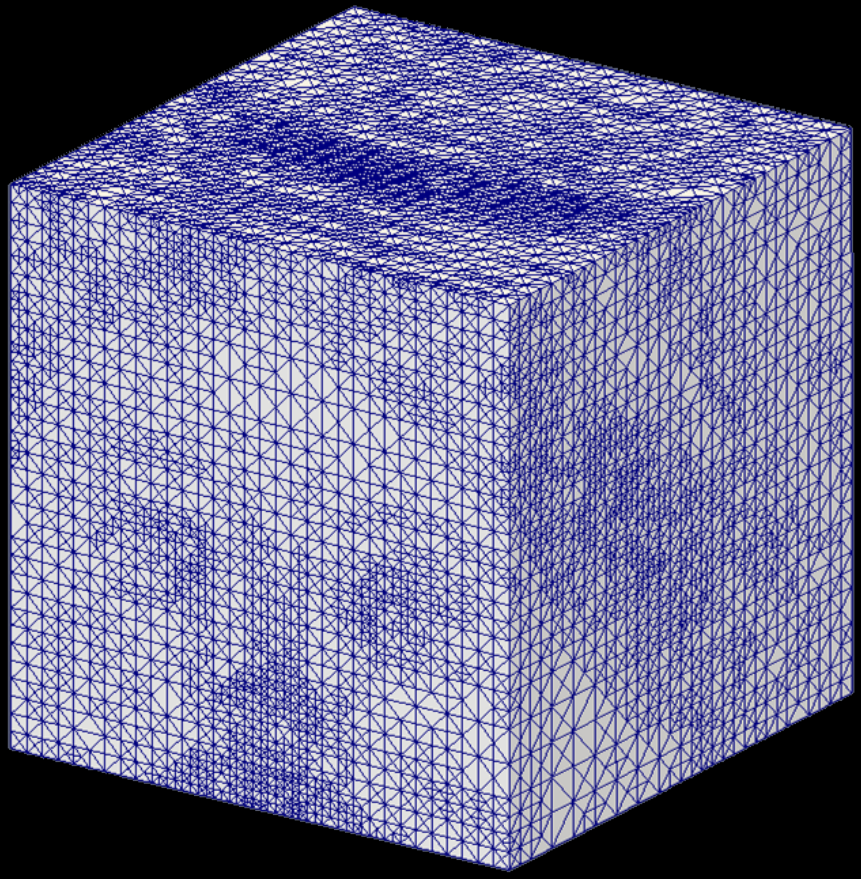
http://www.dca.iusiani.ulpgc.es/proyecto2012-2014

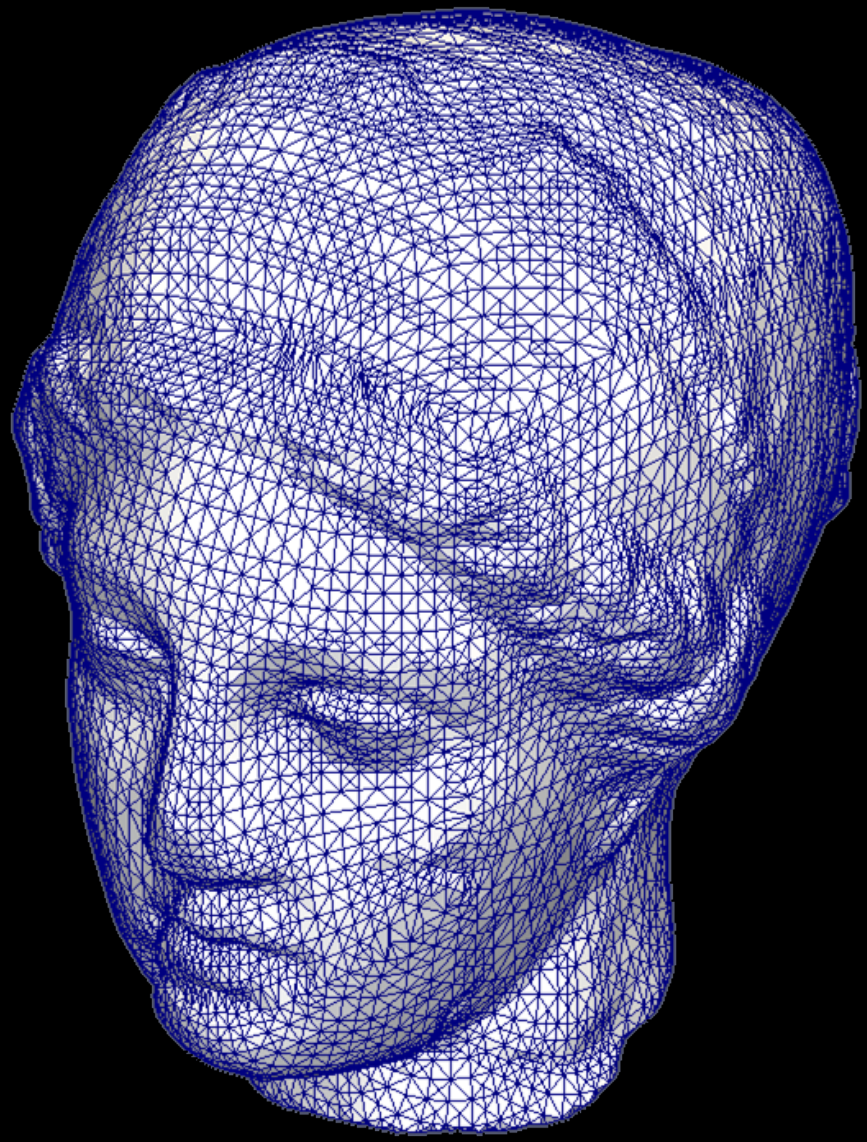
Final Comments and Future Works

Automatic Construction of the Meccano









Adaptive Isogeometric Refinement

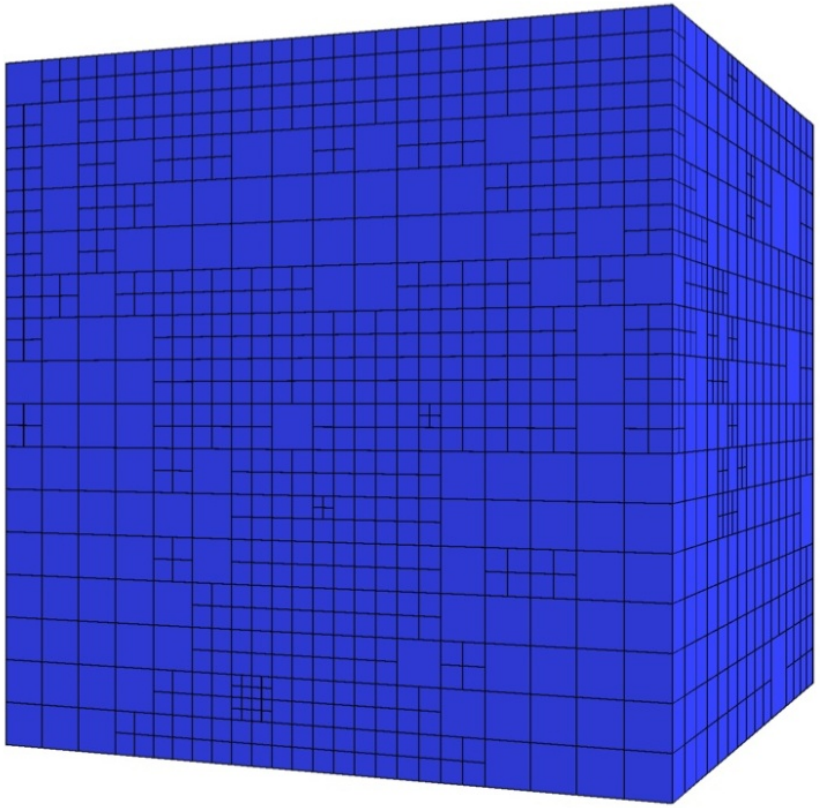
Application in Igea: Poisson problem with a central source

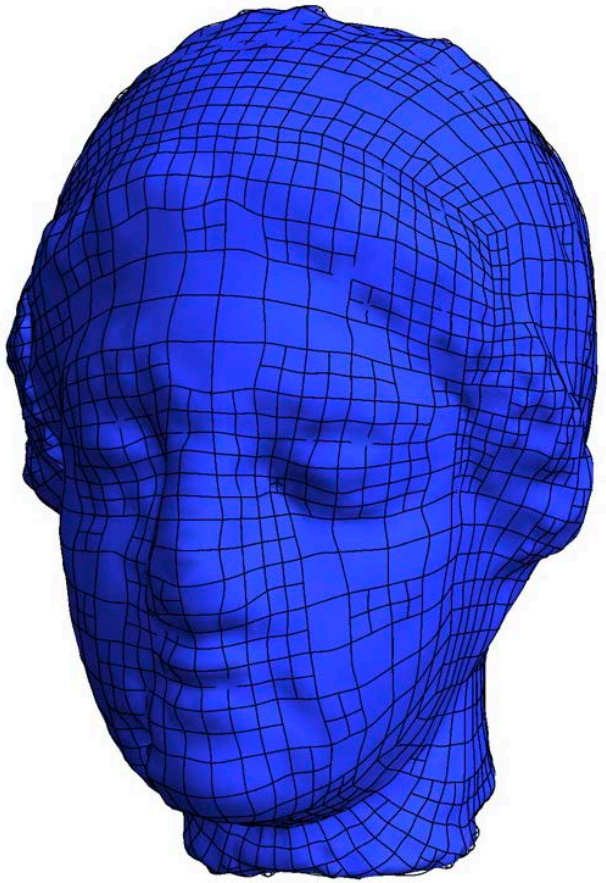
$$\Delta u = \frac{1}{25} e^{-\frac{\left(x^2+y^2+z^2\right)}{10}} \left(-15 + x^2 + y^2 + z^2\right) \quad \text{in } \Omega$$

$$u\big|_{\partial\Omega} = 0$$

Exact solution:

$$u \approx e^{-\frac{\left(x^2+y^2+z^2\right)}{10}}$$

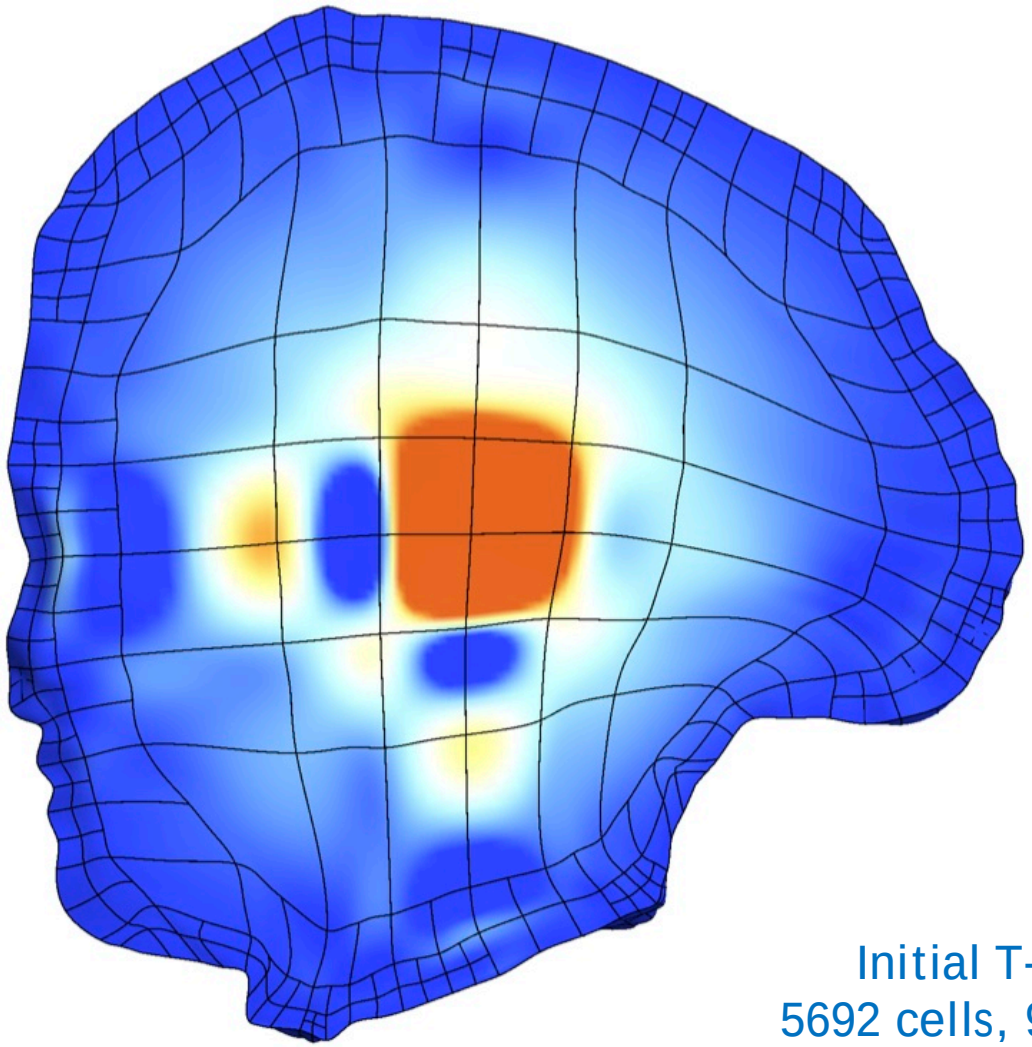


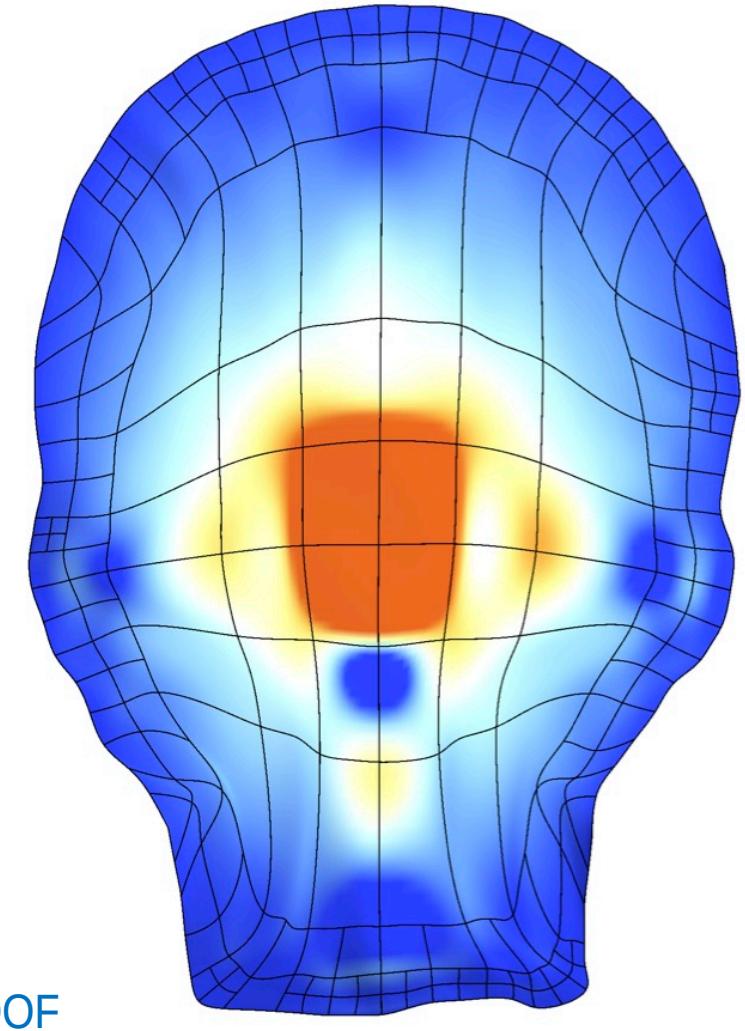


T-mesh $\xrightarrow{\mathbf{S}(\xi)}$ T-spline

Adaptive Isogeometric Refinement

Igea: T-spline of Numerical Solution



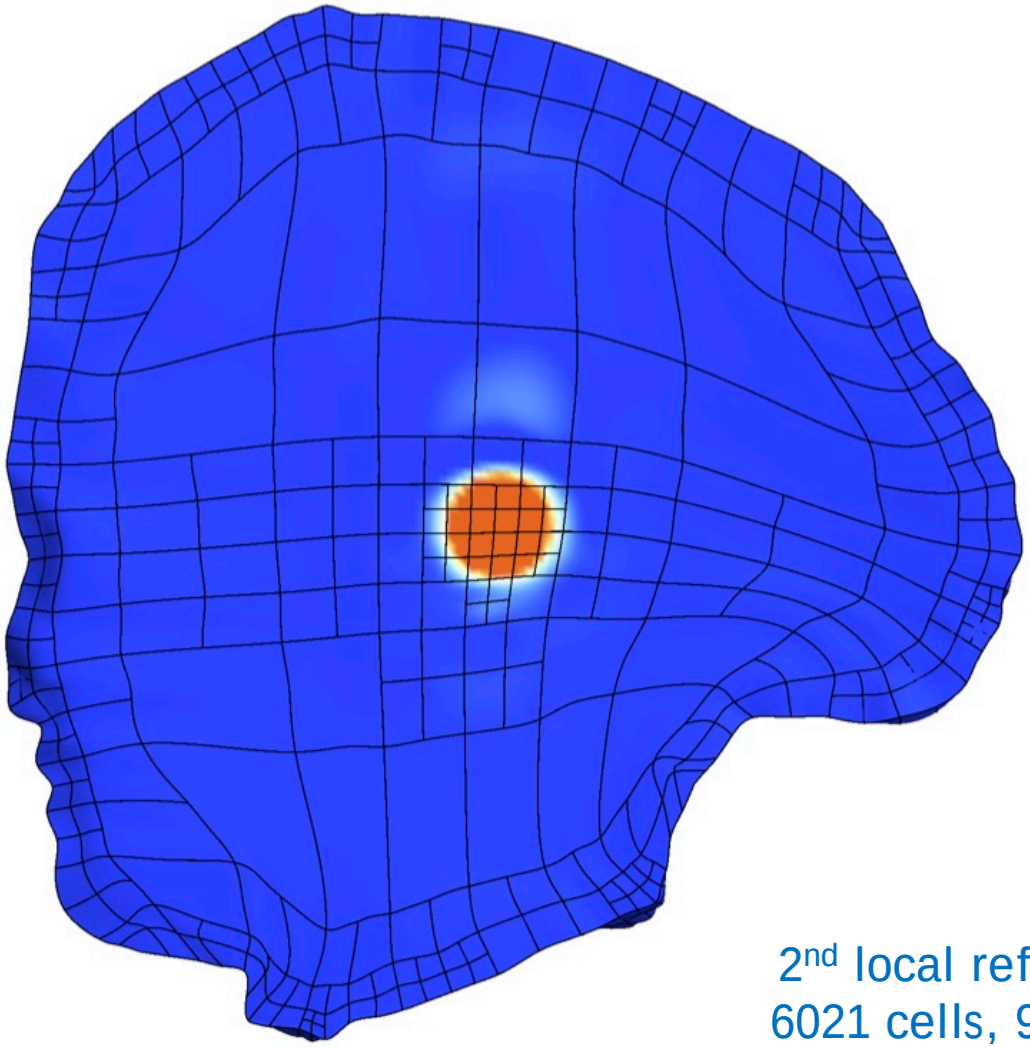


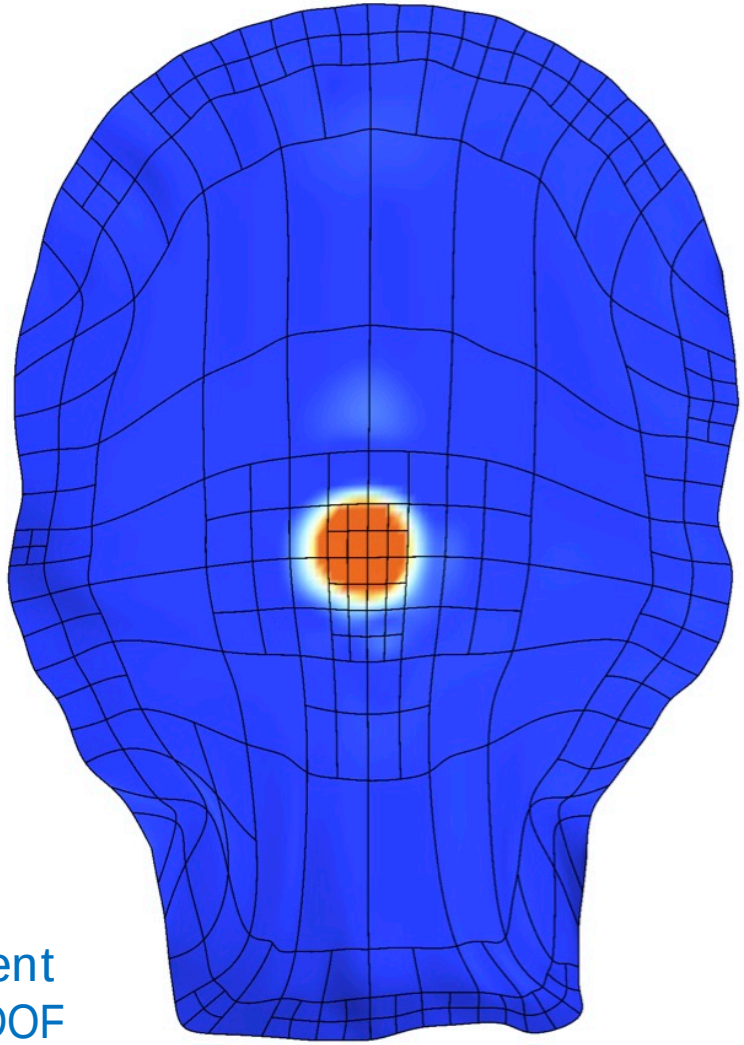
Initial T-mesh
5692 cells, 9304 DOF

Adaptive Isogeometric Refinement

Igea: T-spline of Numerical Solution

Error indicator : $\eta(\Omega_e)^2 = \int_{\Omega_e} h^2 (f + \Delta u_h)^2 \, d\Omega$



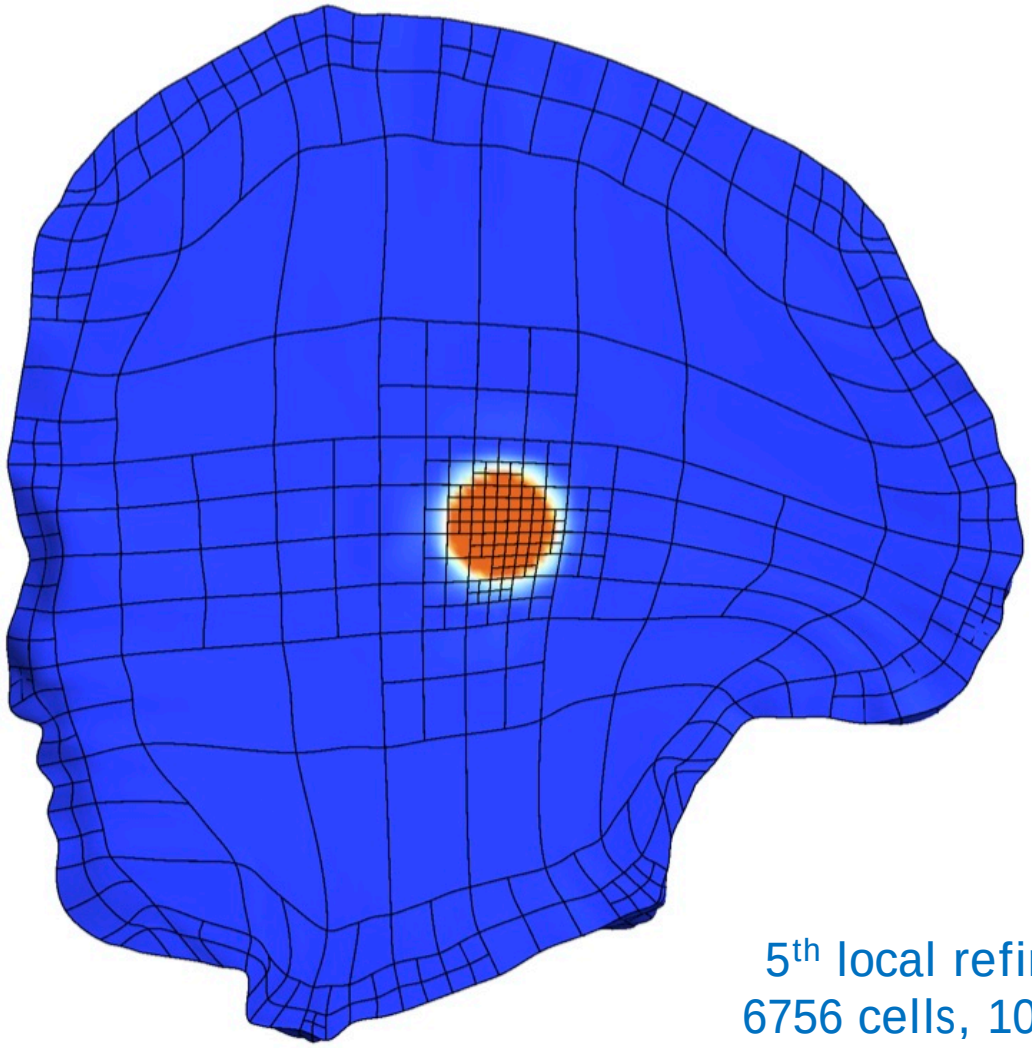


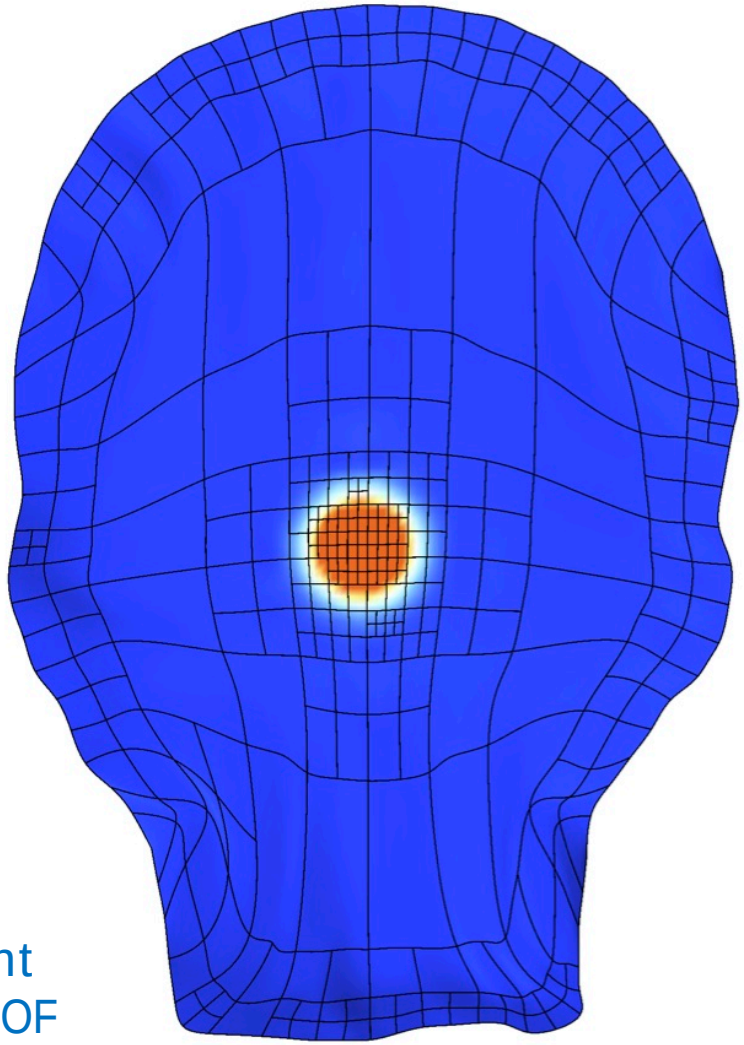
2nd local refinement
6021 cells, 9807 DOF

Adaptive Isogeometric Refinement

Igea: T-spline of Numerical Solution

Error indicator : $\eta(\Omega_e)^2 = \int_{\Omega_e} h^2 (f + \Delta u_h)^2 \, d\Omega$





5th local refinement
6756 cells, 10838 DOF