Overview of R&D on 3D Geological Modelling at BRGM

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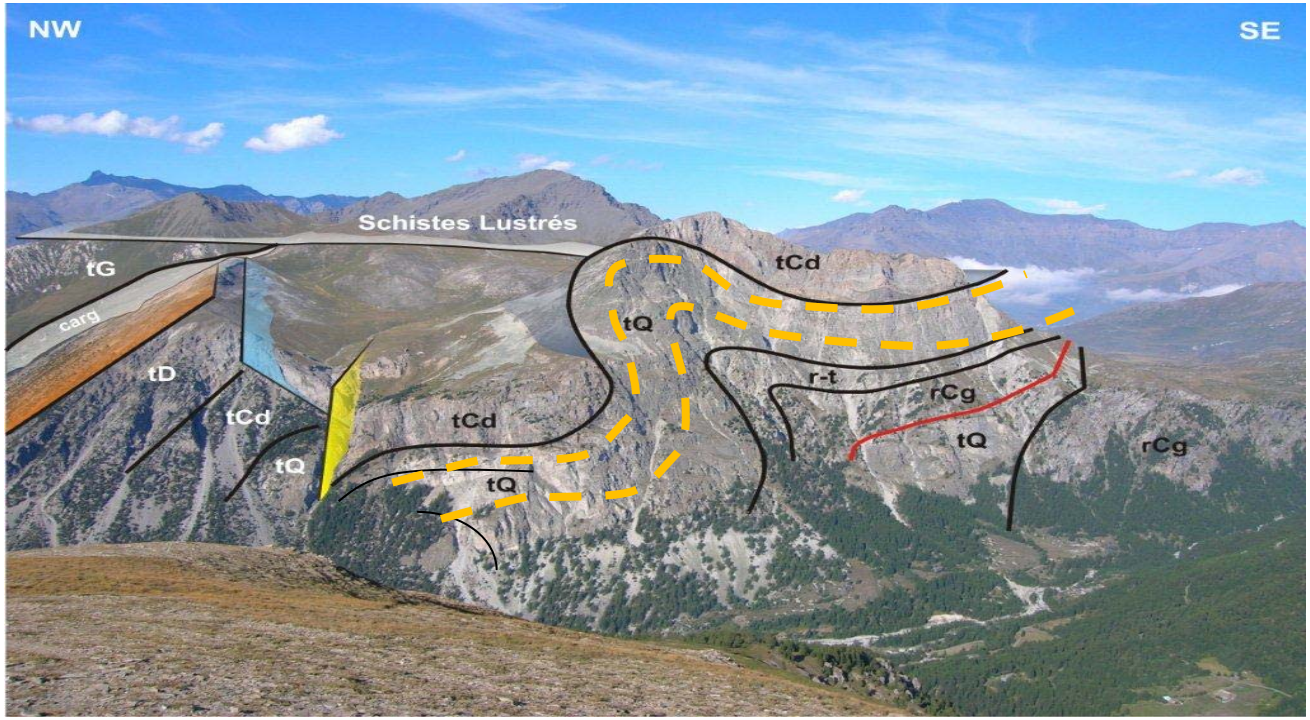
[1] BRGM,
[2] Ecole des Mines de Paris



Improve Geomodelling capabilities

- **Improve modelling algorithms: Variable anisotropy, faults**

- **Meshing and multi-physics simulation**
- **SeismicTomography/gravity inversion**
- Storing and delivering geological models (Loiselet et al. this session)
- Dealing with geological uncertainties
- Geological architecture (Calcagno et al., this session)
- Integration of cavities or anthropic infrastructures (see Allanic et al., Beaufils et al.)

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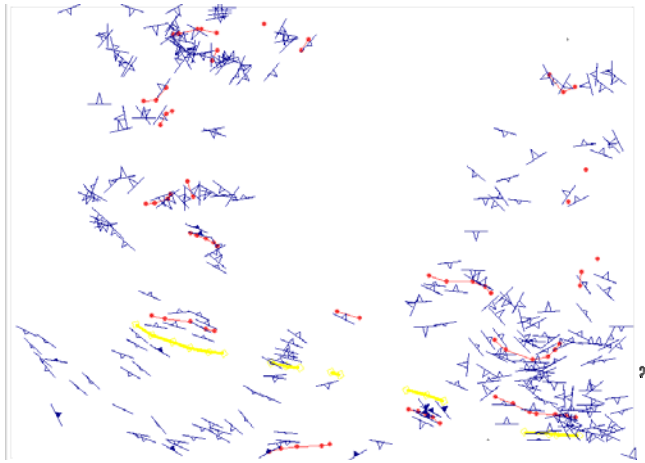
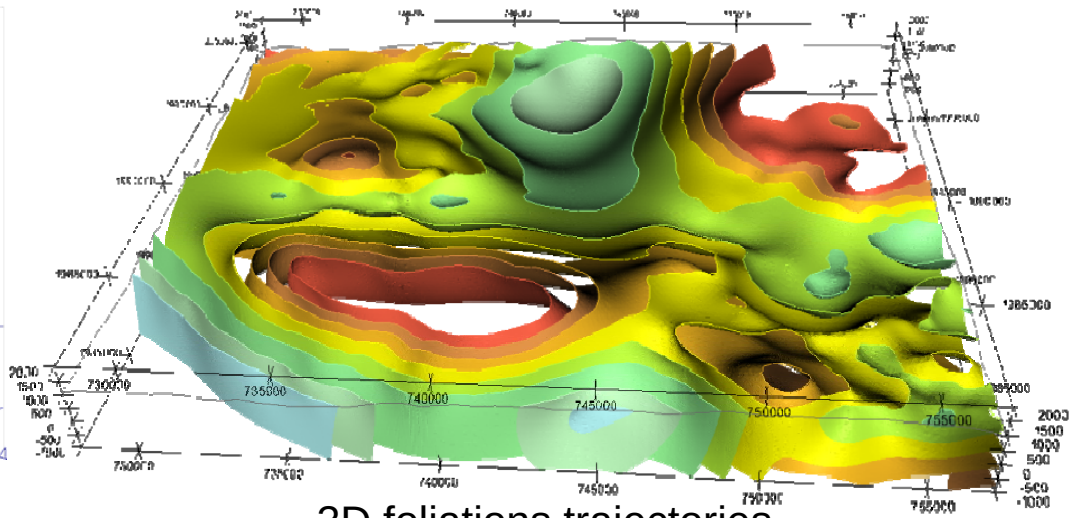
Potential cokriging method recalls



Field data set



3D foliations trajectories

Based on an original interpolation method that takes into account orientation data and interface acquired in geological units on the field (contacts, stratifications, cleavage, strain field).

Interpolation method : Dual Cokriging a 3D potential field and its derivatives : data contacts represent particular sampled values of this field. Orientation data represent particular sampled gradients values of this field. Geological surfaces are designed as implicit surfaces extracted from the computed field (iso-values).

(Lajaunie et al., 1997, Courrioux et al. 2001, , Aug, Chilès 2004, Calcagno et al., 2008).

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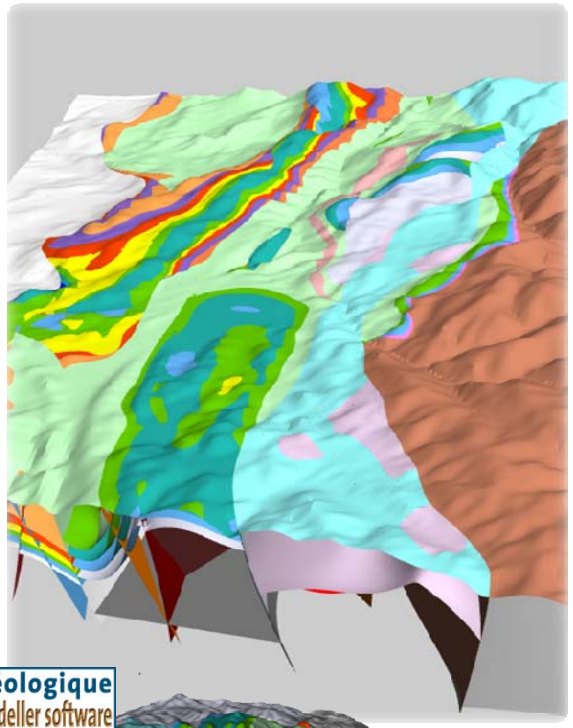
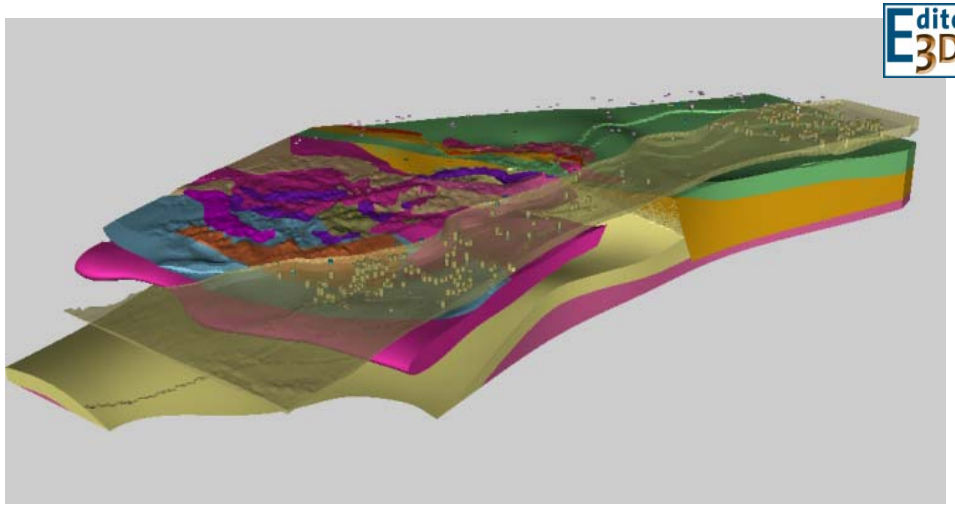
Potential cokriging method recalls

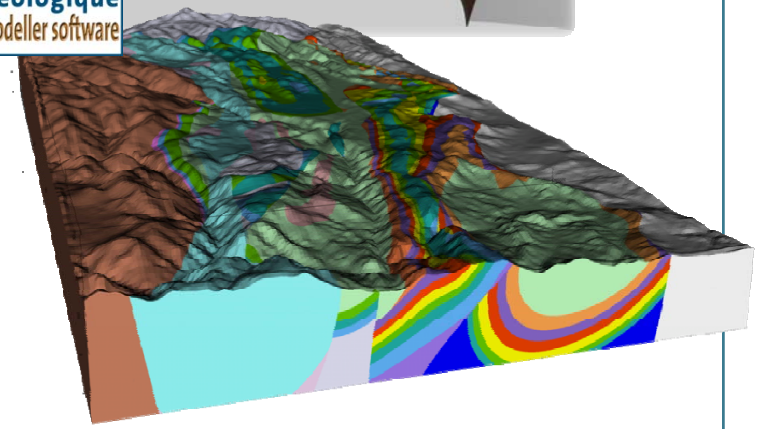
Geological Modelling

- Assemblage of different fields with respect to geological and chronogical relationships (→**Pile**)
- allows to design a complete volumic model of different geological units.

→Adapted to complex geological contexts (folded, metamorphic and intrusive)

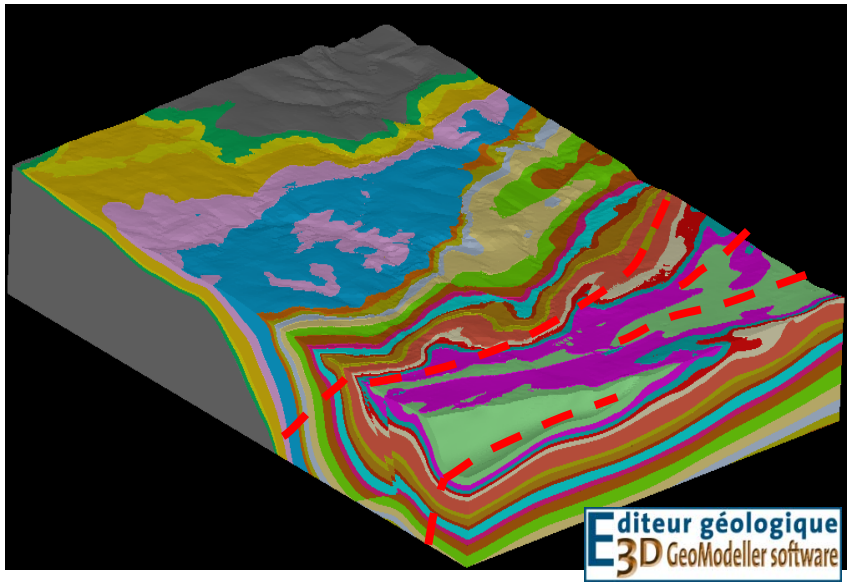






Allanic et al., 2016

Folds and anisotropy



- Geological objects have a natural anisotropy which is varying in space.
- Accounting for anisotropy factors is crucial for a realistic geological modelling folds, deformed intrusive, meandering
- alluviums …
- This anisotropy is related to field features such as fold axial planes, fold axis, intersection lineations …

> The idea is to use anisotropic covariance parameters in order to improve the interpolation of folded structures.

> Parameters should be variable in space according to an anisotropy field

> → Reduce uncertainties

> ***See also :***

- ***Hillier et al., 2013, 2014;***
- ***Laurent et al., 2015;***
- ***Carrera et al., 2009.***

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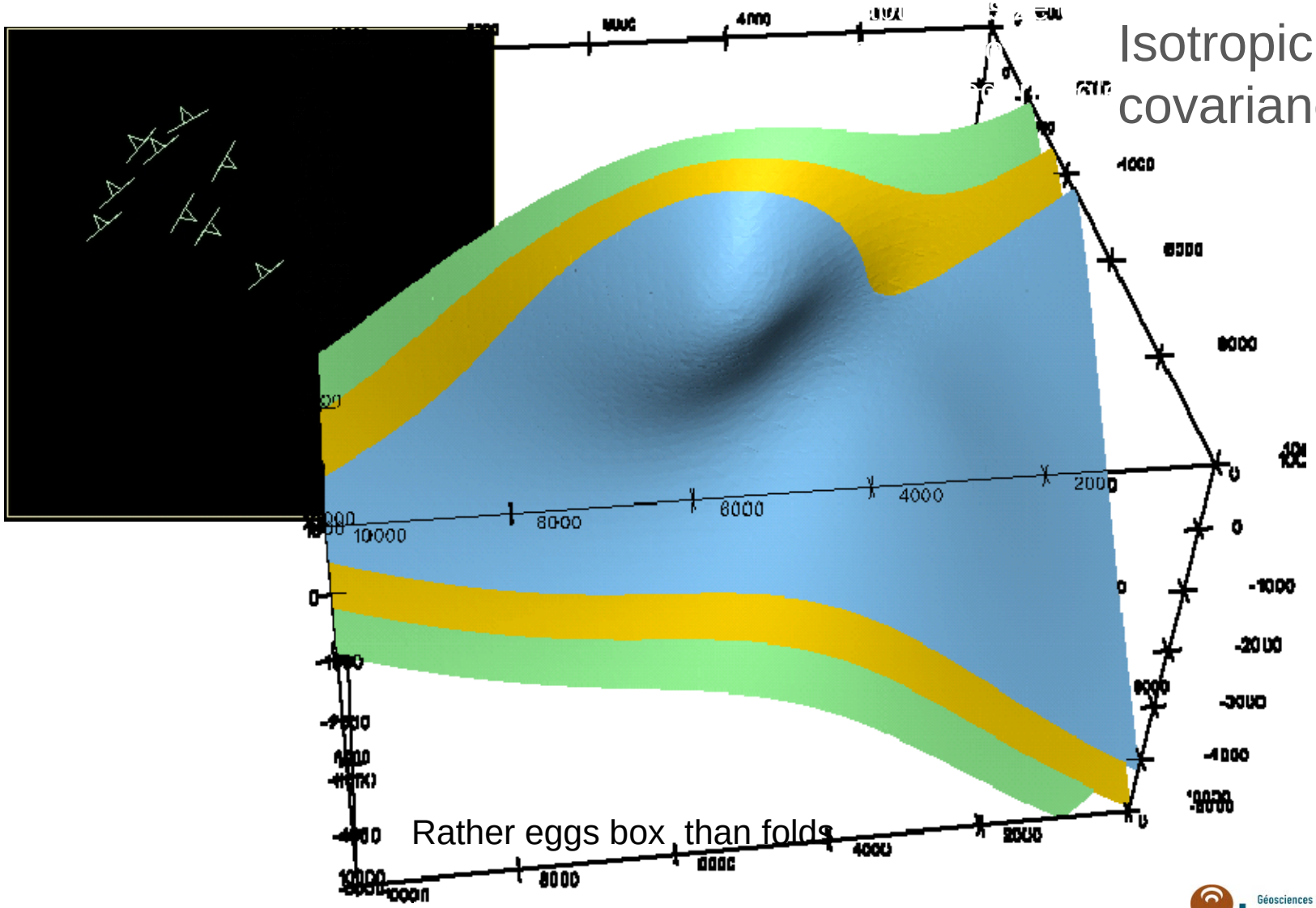
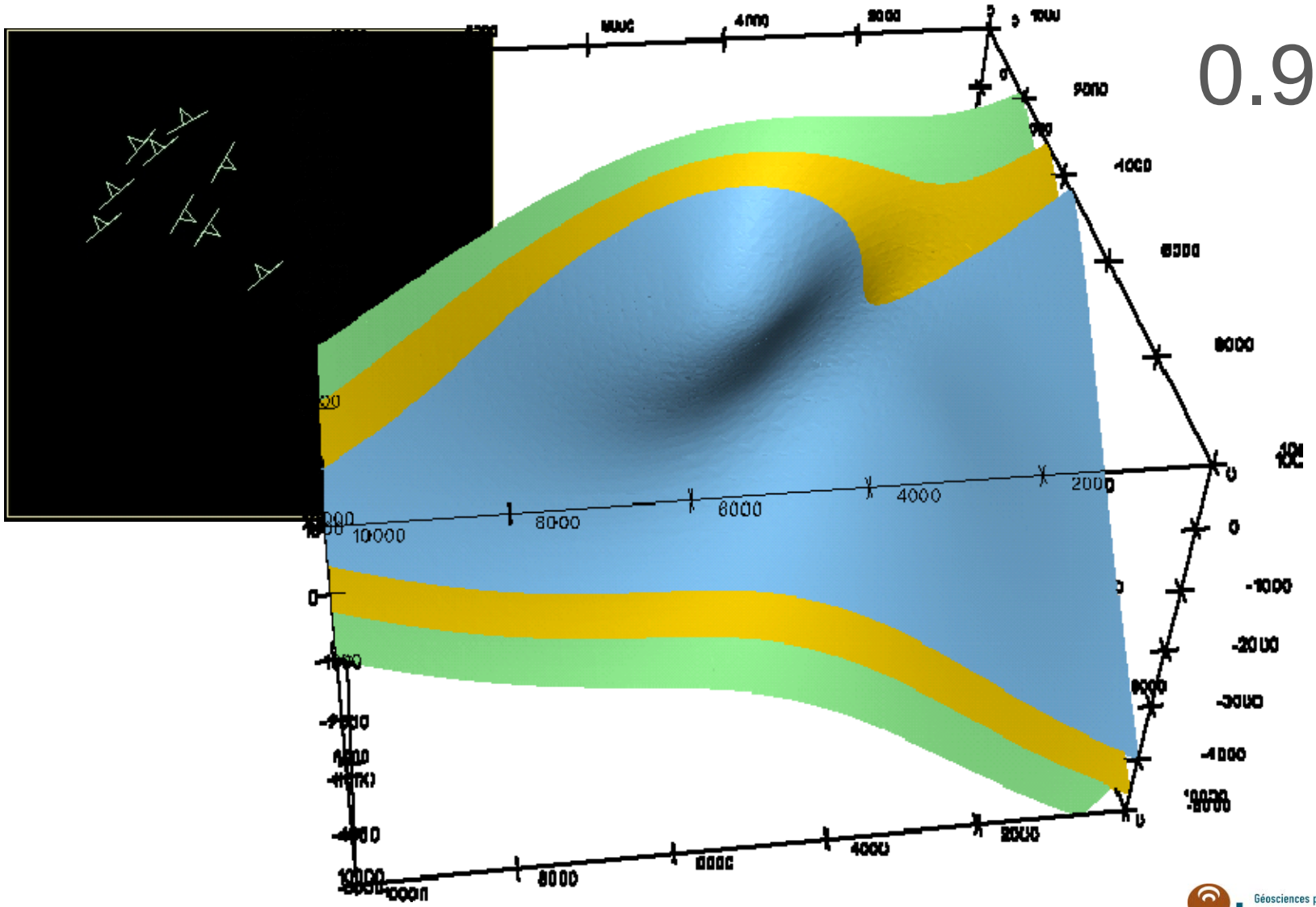
Relations between folds and anisotropy



Relations between folds and anisotropy



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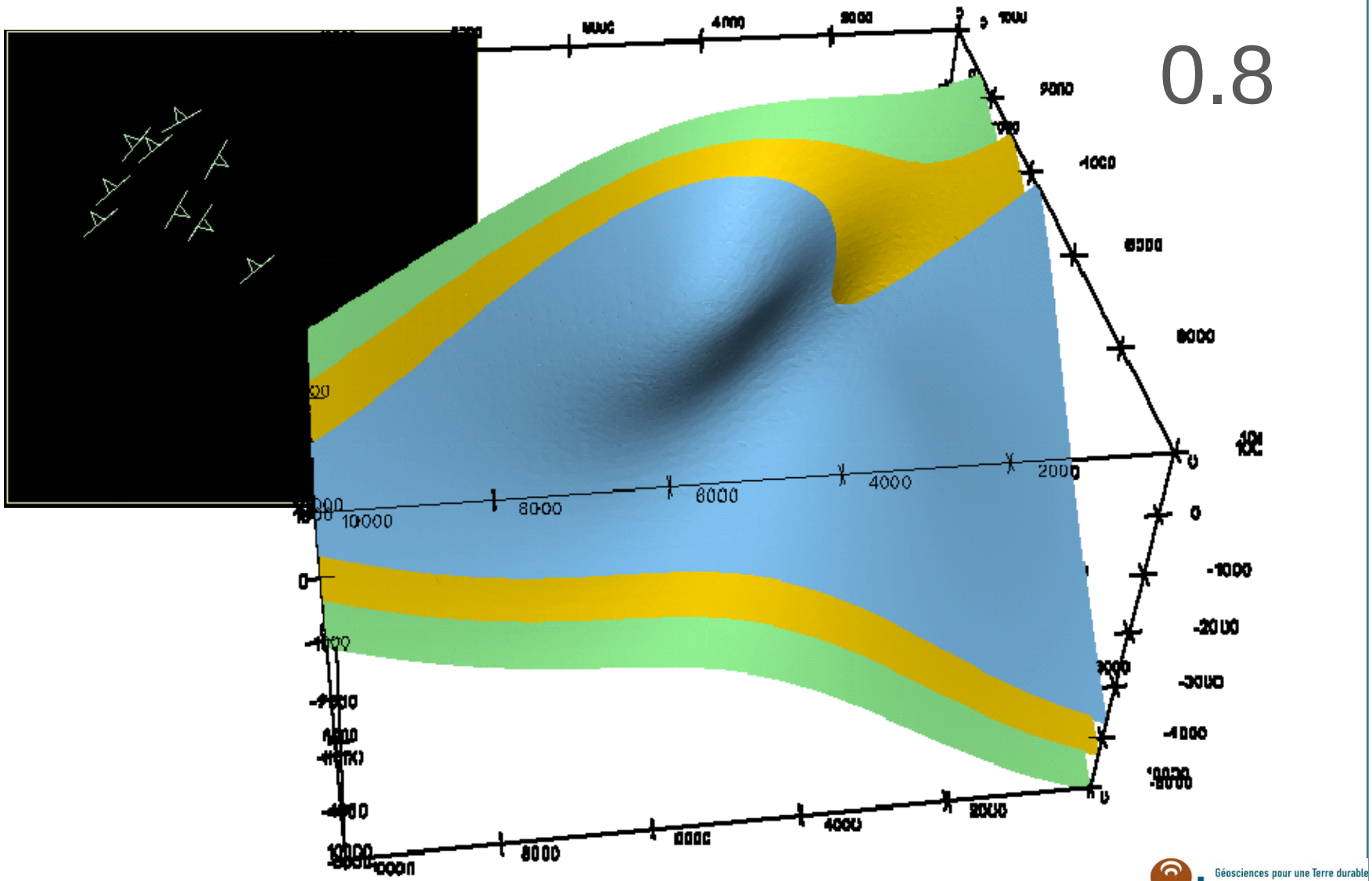
Relations between folds and anisotropy



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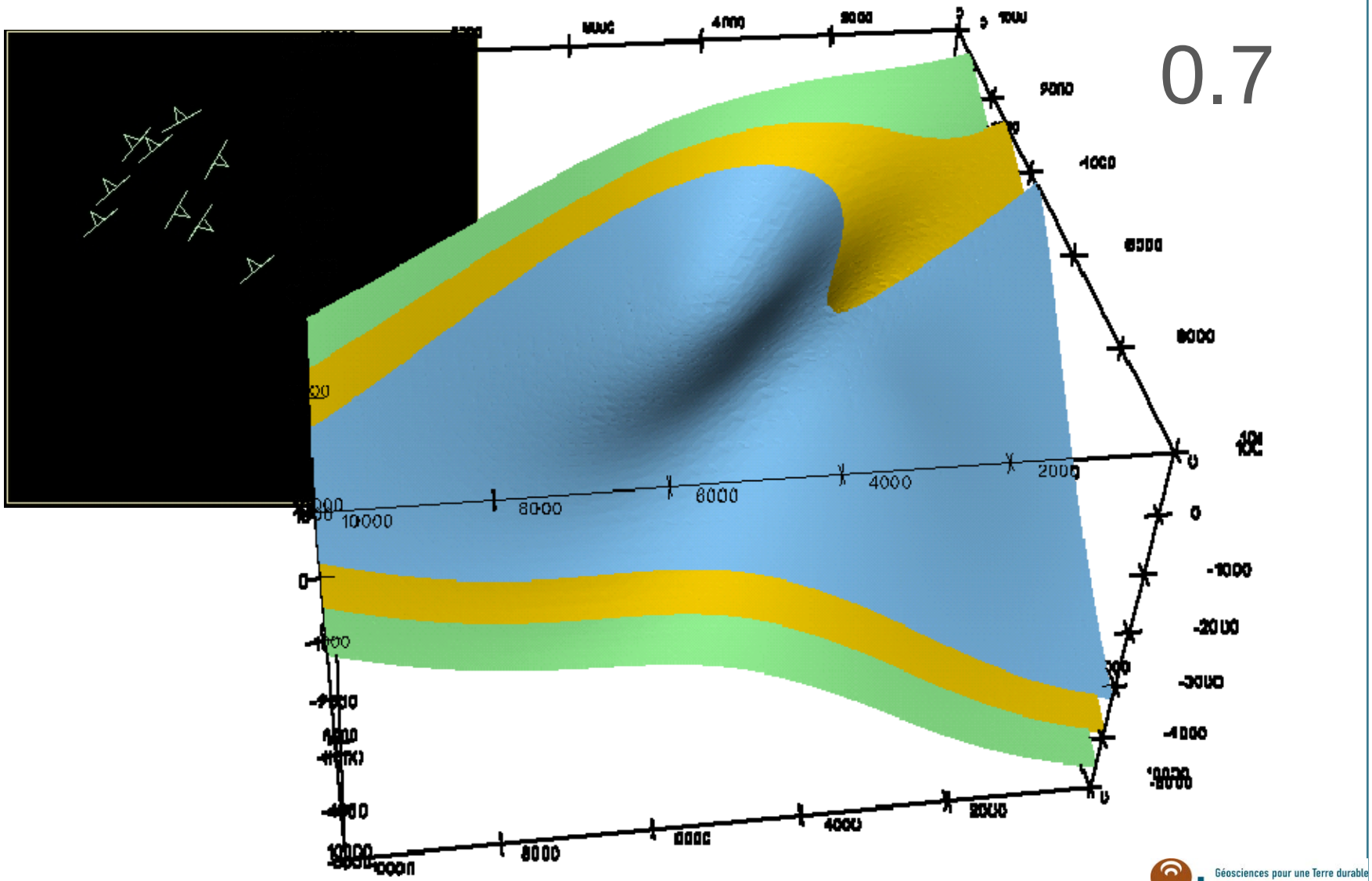
Relations between folds and anisotropy



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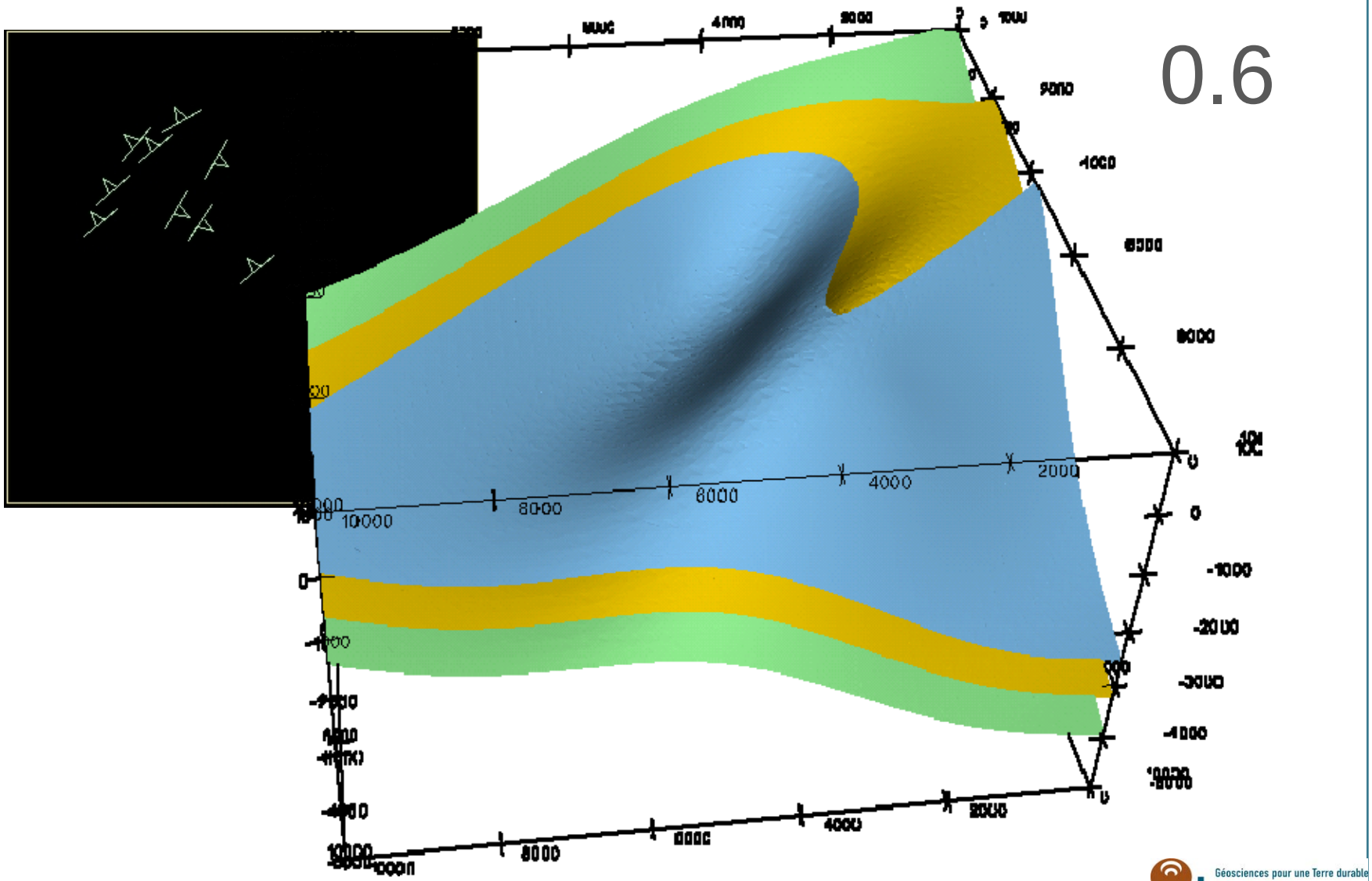
Relations between folds and anisotropy



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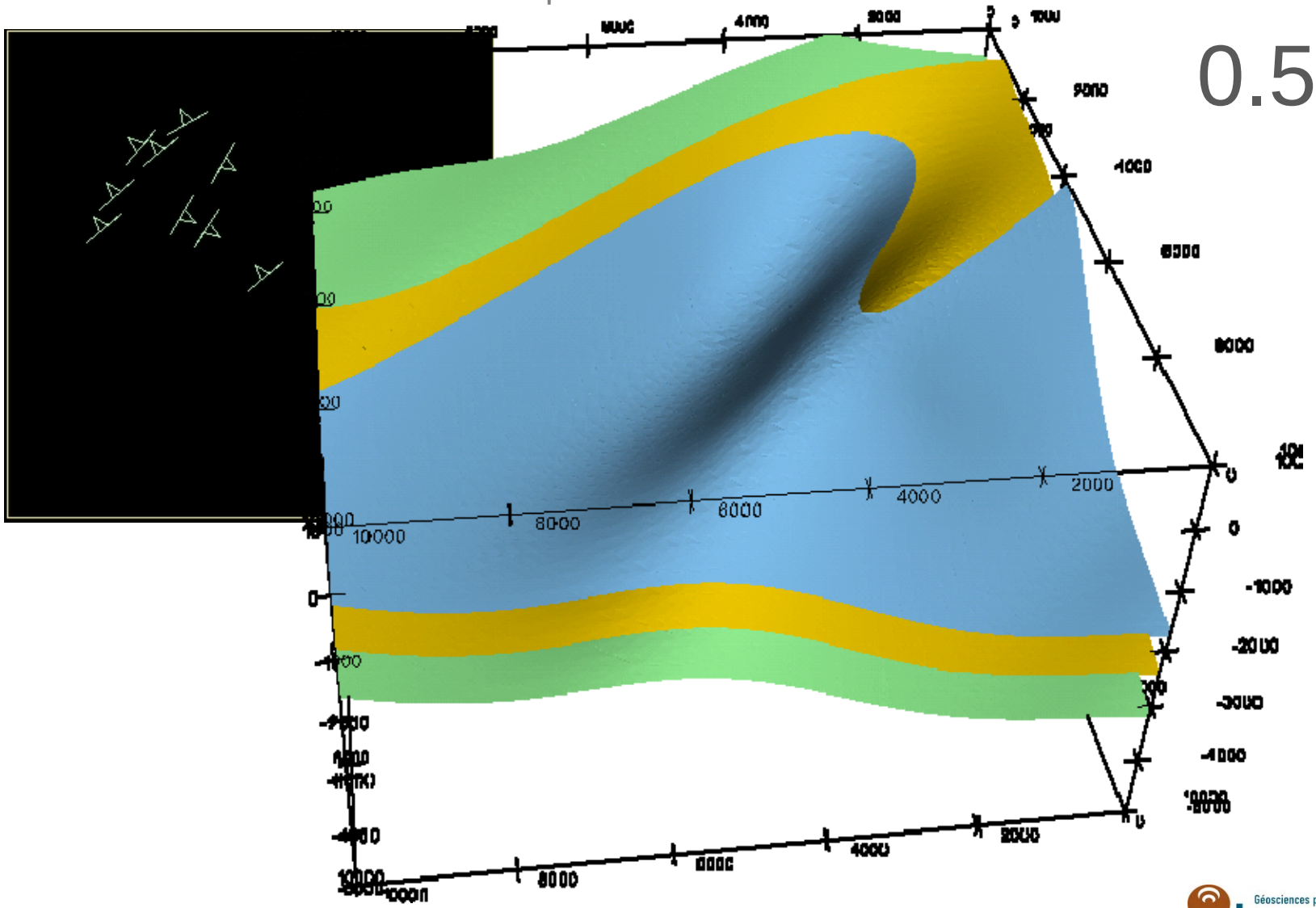
Relations between folds and anisotropy

Isotropic covariance.



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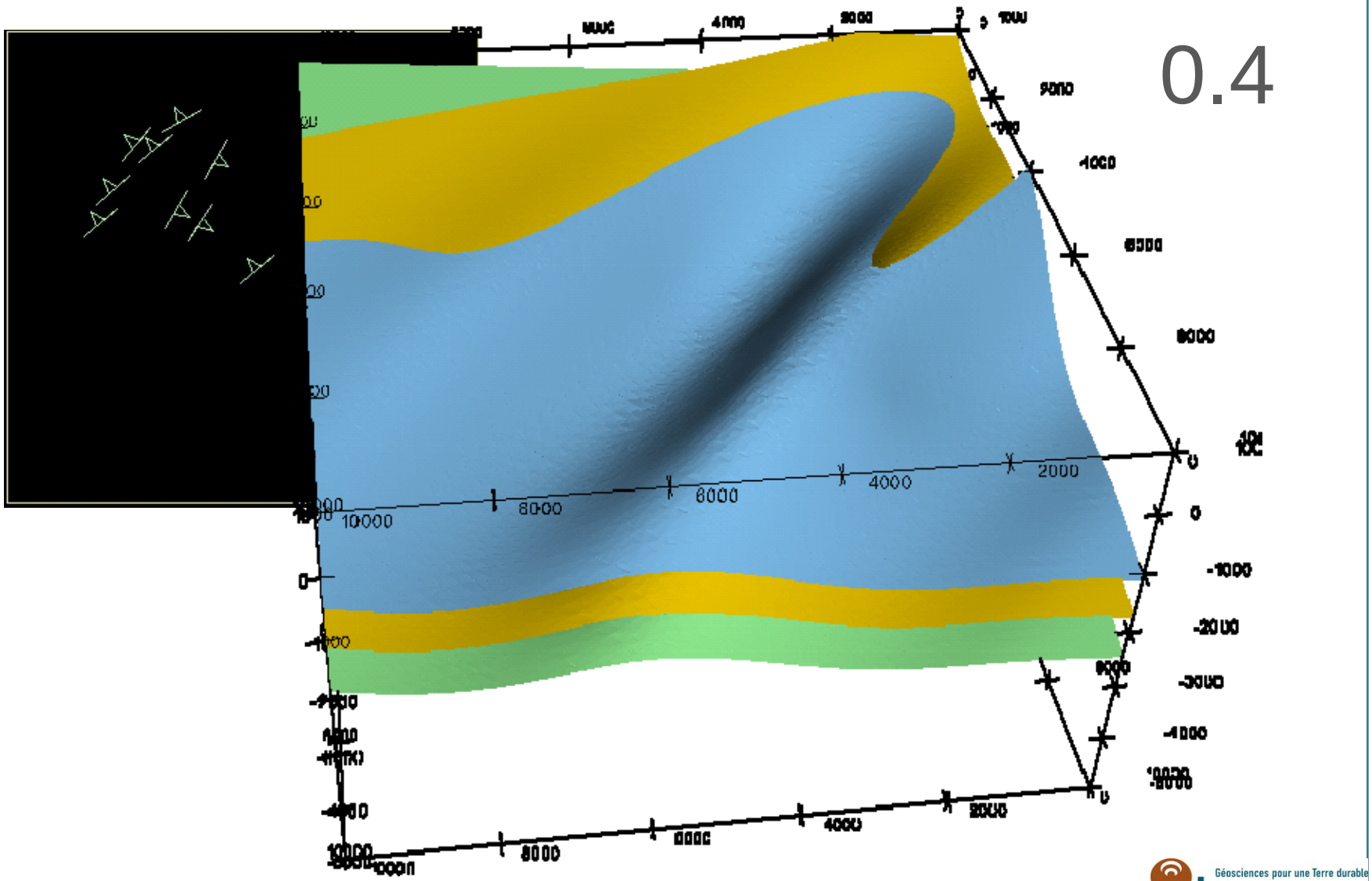
Relations between folds and anisotropy



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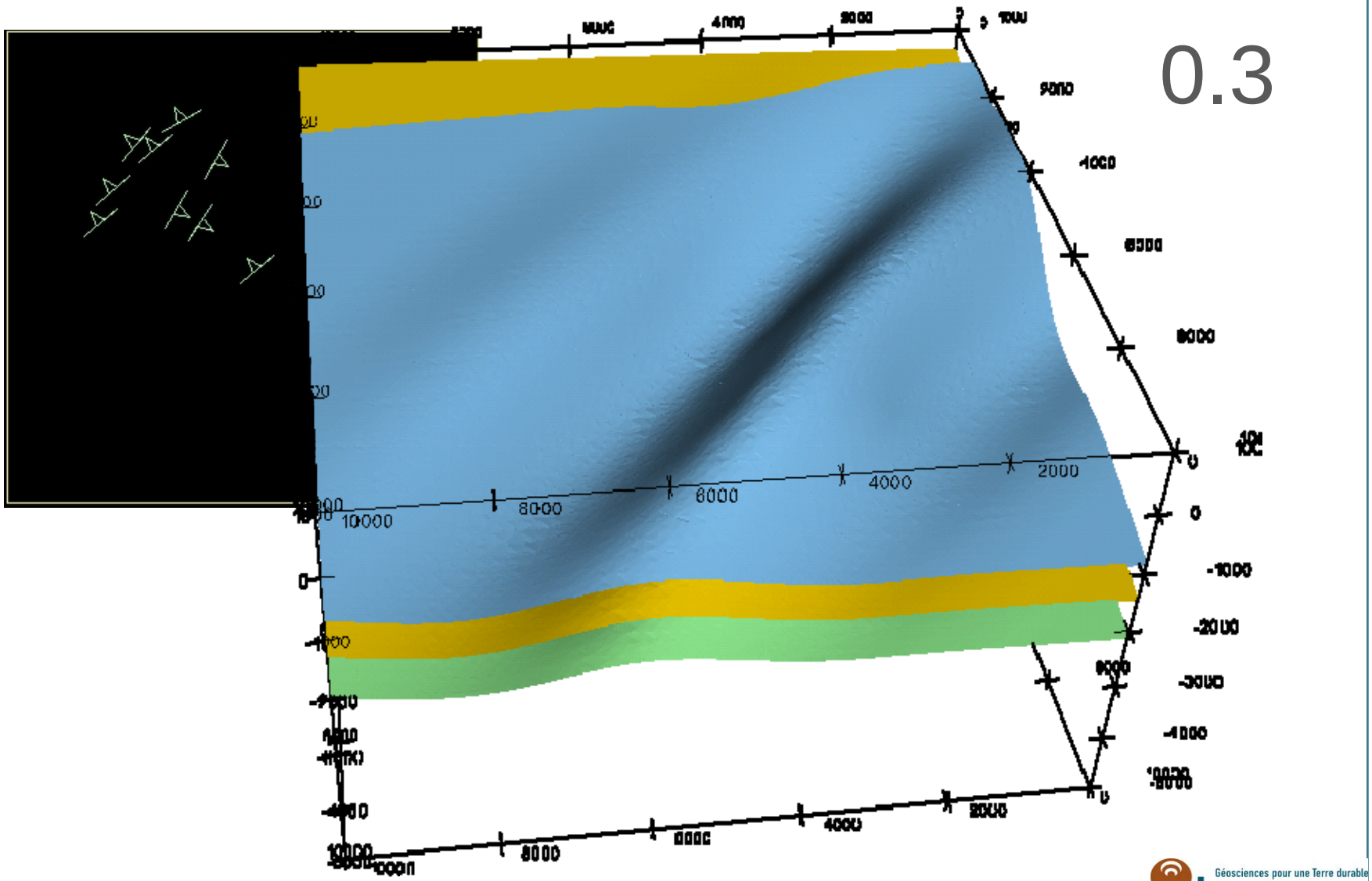
Relations between folds and anisotropy



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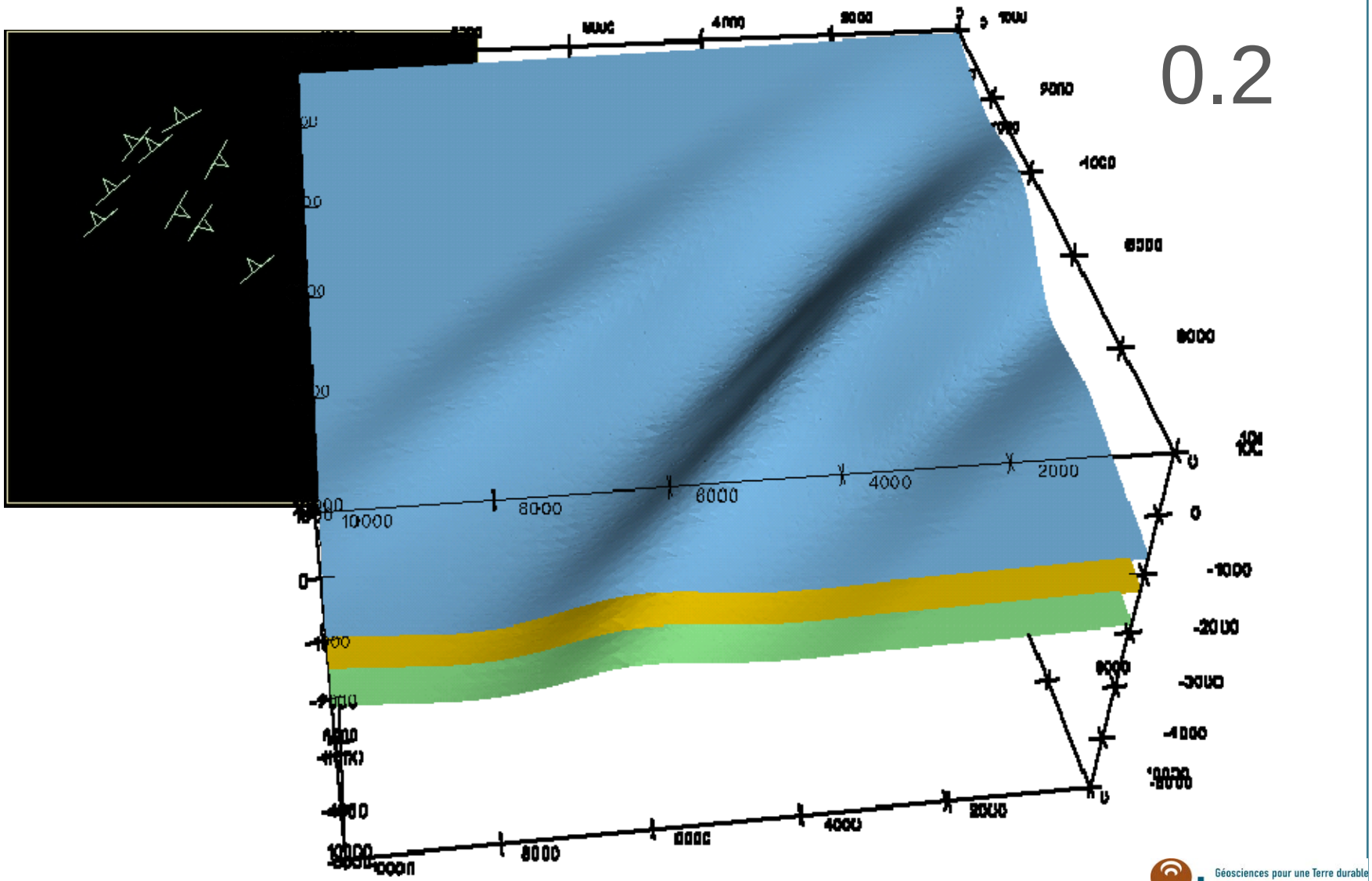
Relations between folds and anisotropy



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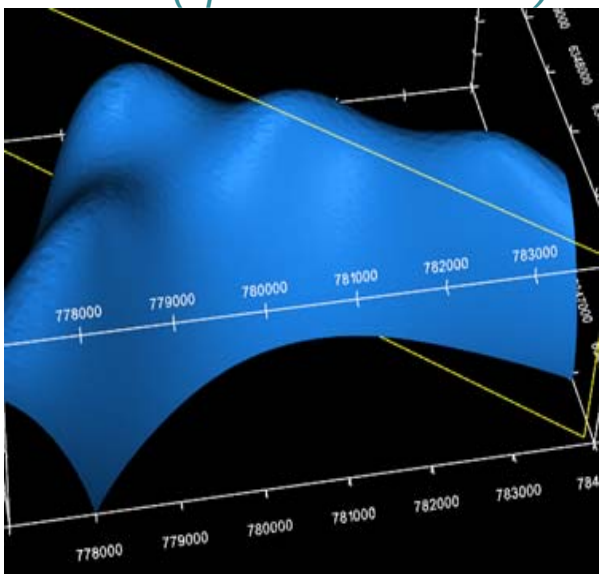
Ongoing research

Variable anisotropy

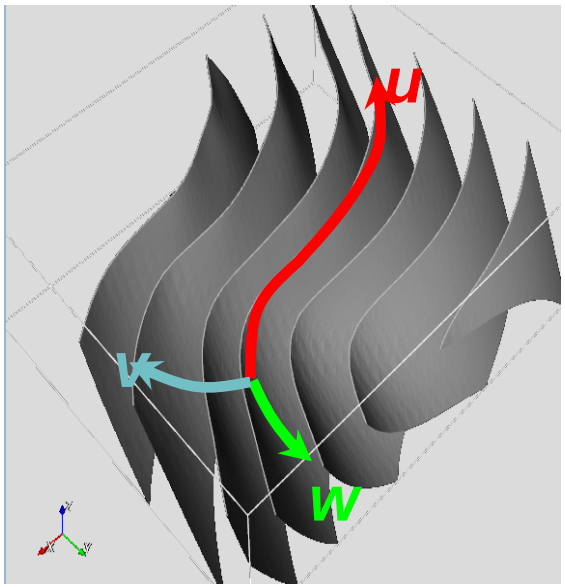
Thesis in collaboration with Paris School of Mines.

Laure Pizzella

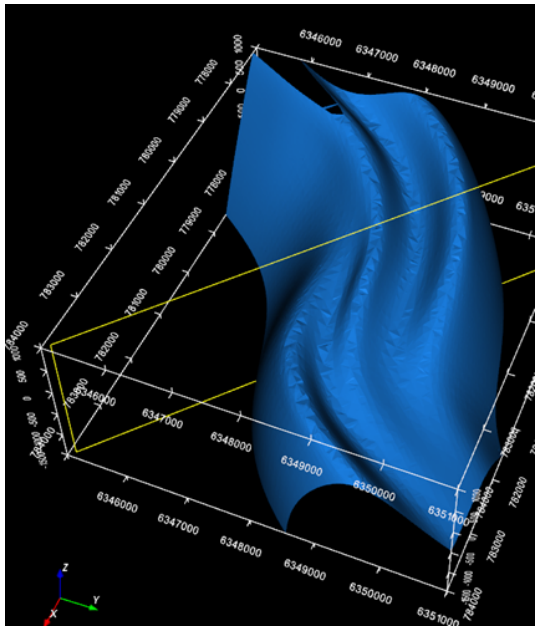
Track 1 (space deformation)



Rather “bubble” shapes
If not accounting for anisotropy



- Anisotropy tensor field varying in orientation and intensity, interpolated from structural data (fold axis, schistosity, strain rate)
- This allows to define a new space coordinate in the anisotropy field *x,y,z* → *(u,v,w)*

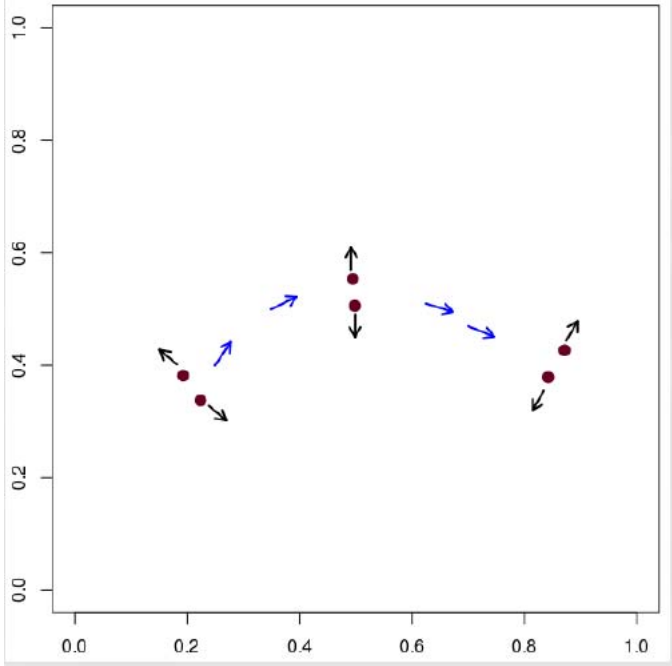


Cokriging is performed using a distance computed on anisotropy field.

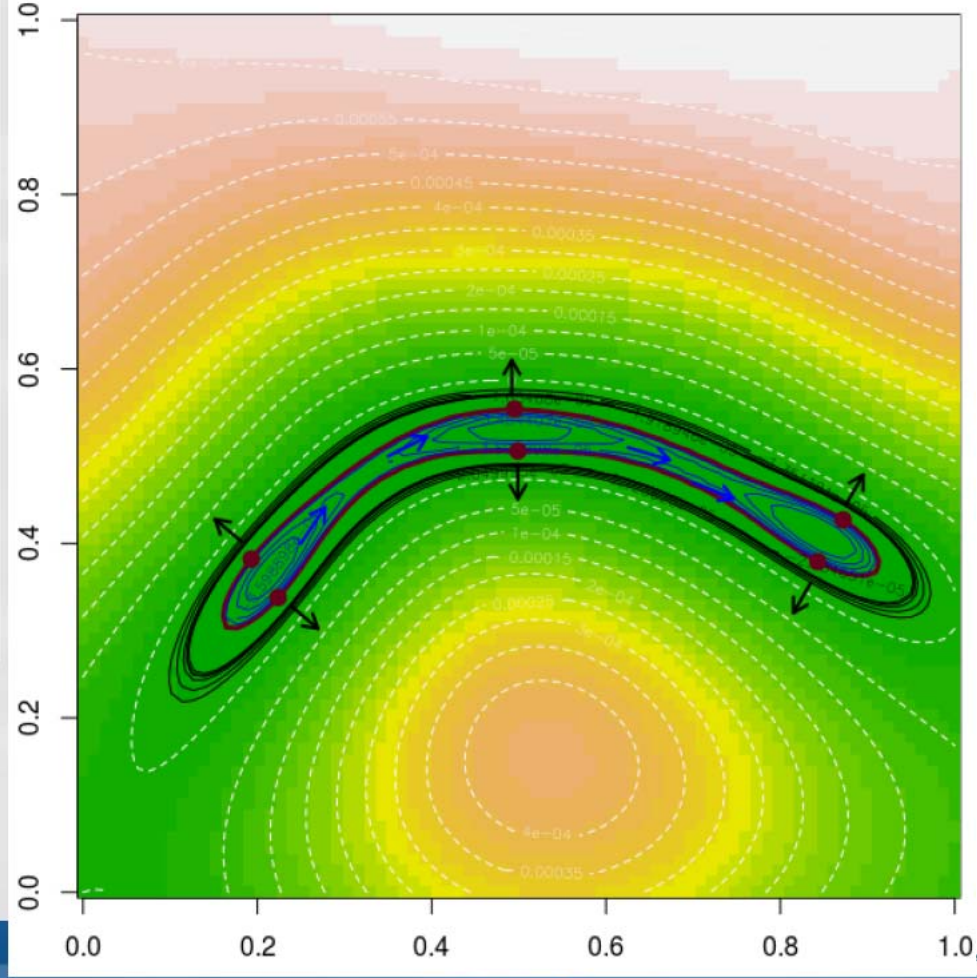
Work in progress with Laure Pizella S

chool of mine of Paris→ other tracks

Second-order derivative method

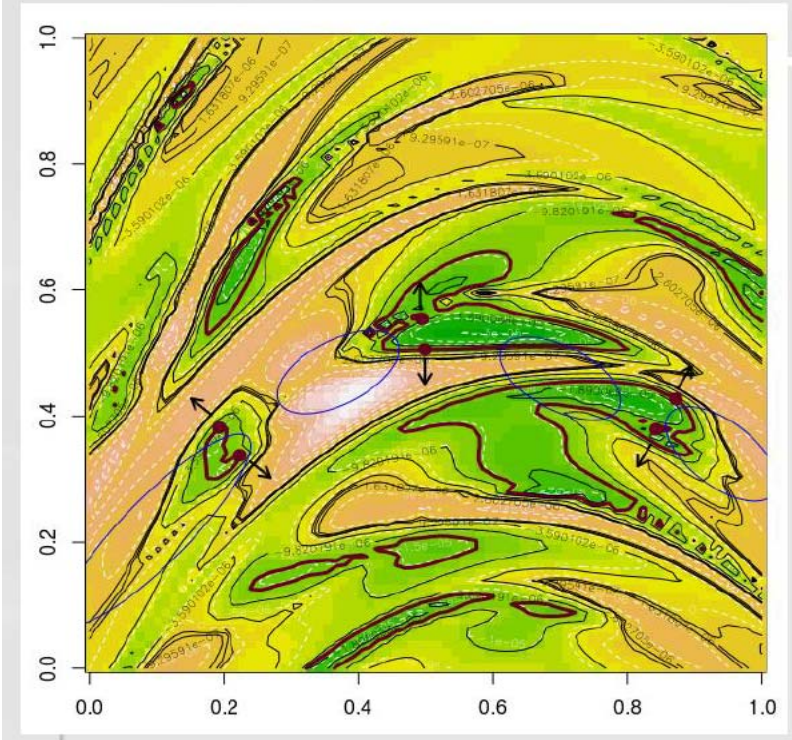


- 4 points of second-order derivative data

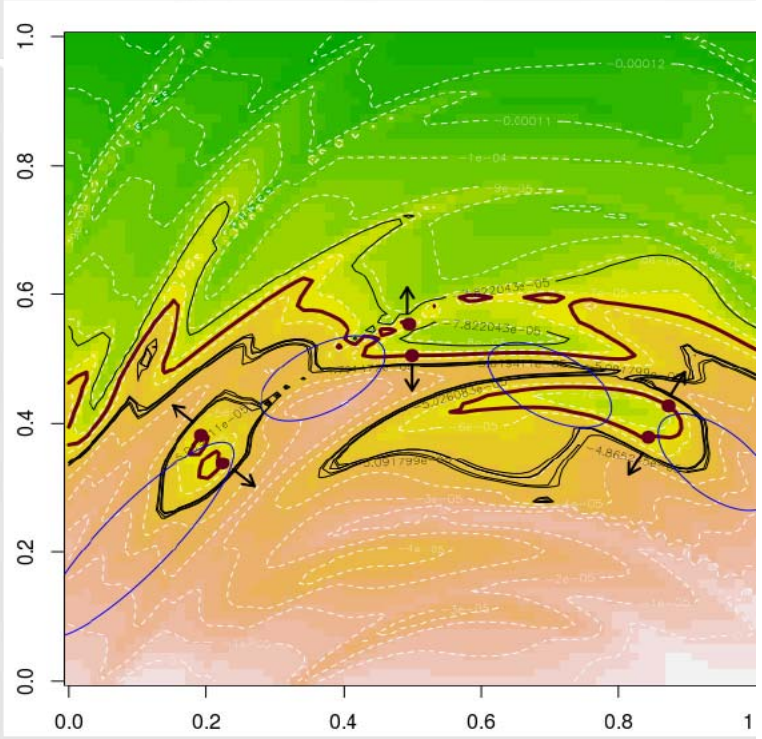


Convolution method

$$4.\ \theta(x) = ax^2 + bx + c + dy$$

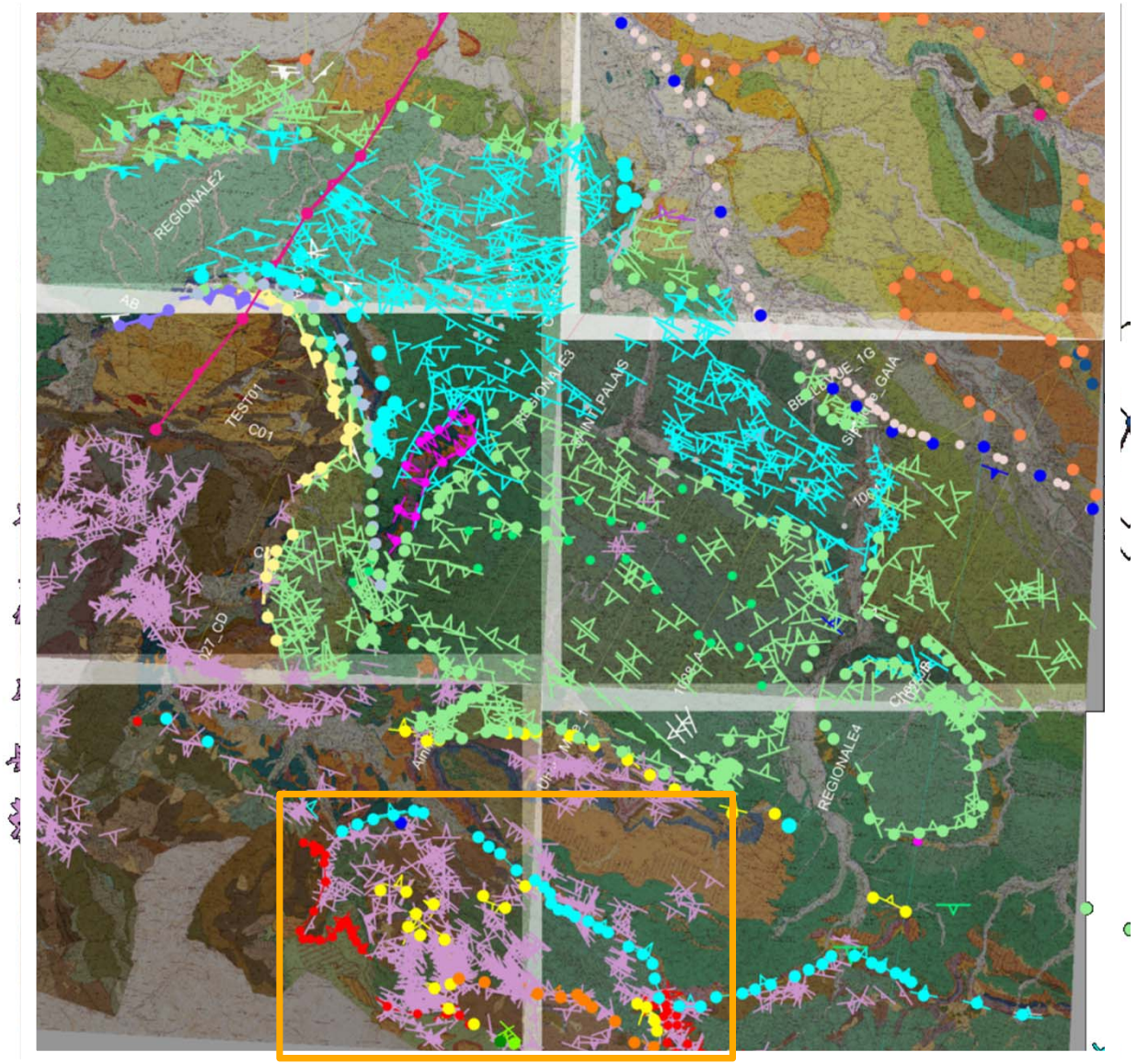


No drift



First-order drift

Mauleon 3D structural model



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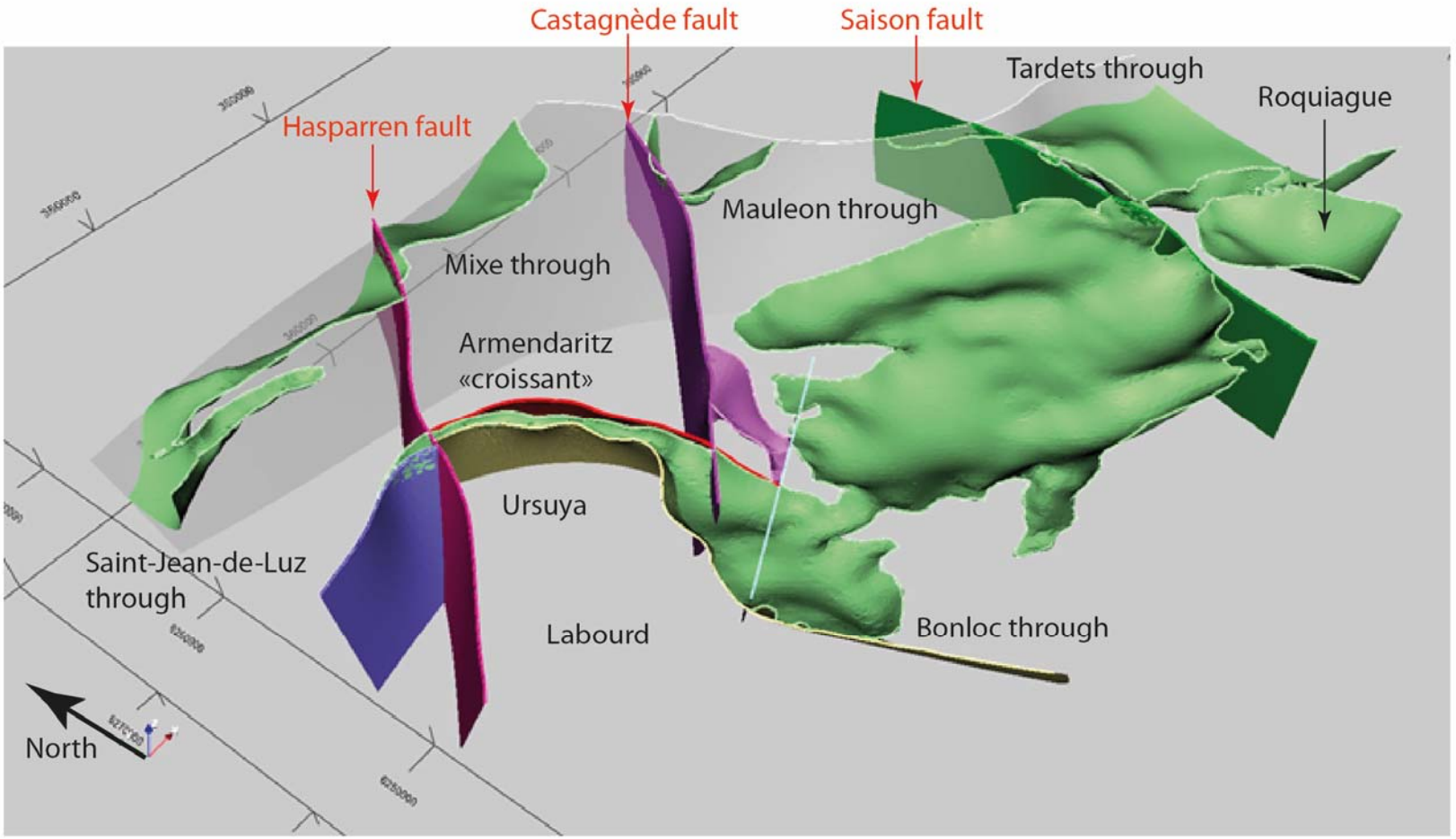
Mauleon 3D structural model (Pyreneees)



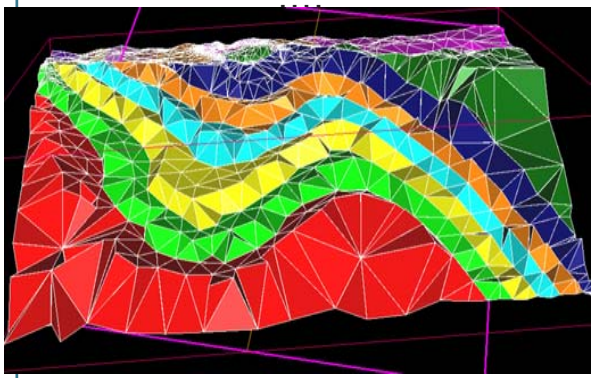
> **Interference between folds and diapiric structures**

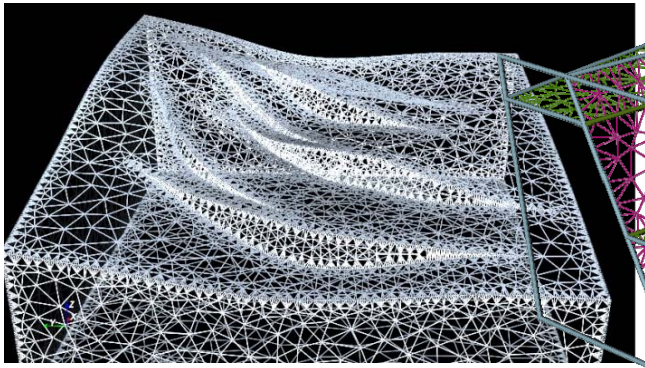
- Accounting for variable anisotry would improve the modelling.

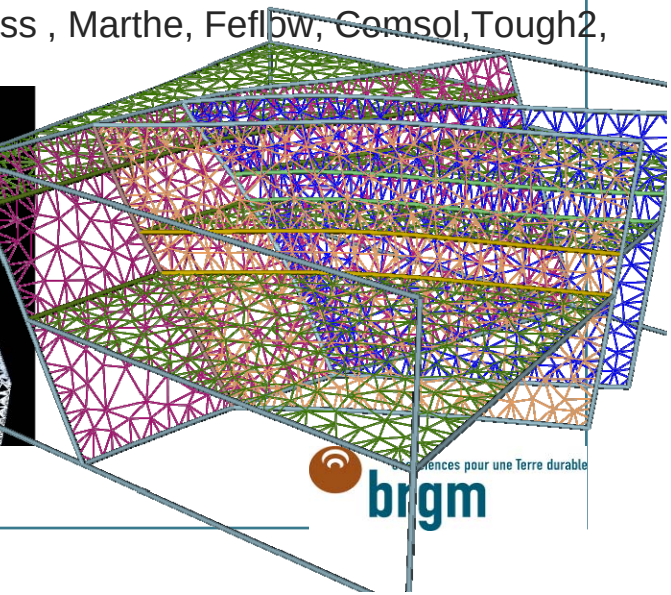
Links between geomodels and simulations : meshing remains a crucial issue

INRIA - Geometry Factory Collaborations :
Laurent Rineau , Andreas Fabri Jean-Daniel Boissonnat, Mariette Yvinec,

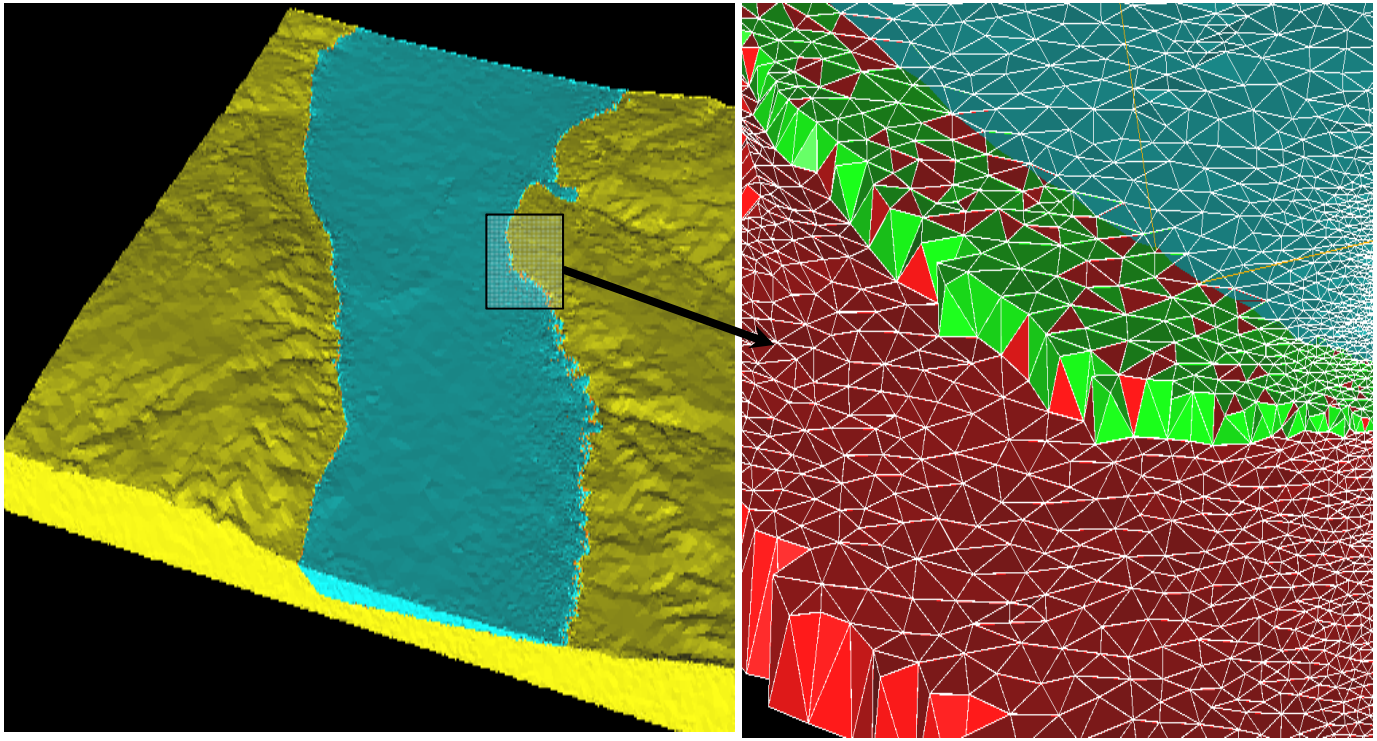
- **Meshing problematic**
  - Diversity of applications and physical domains → as many requirements for meshing type
  - Obtain a conformable mesh to faults and layers boundaries, described by implicit functions.
  - Respect of singularities, sharp angles …
  - Respect of internal anisotropies (in relation with previous subject)
  - Use of CGAL Library (Computational Geometry Algorithms) (Geometry Factory spin-off of INRIA Nice) (see Sébastien Loriot – poster session)
  - Use of tetrahedral meshes for simulation process (flow , thermic, mechanics, restoration …)
    → Coupling with simulation software or codes : Compass , Marthe, Feflow, Comsol,Tough2,





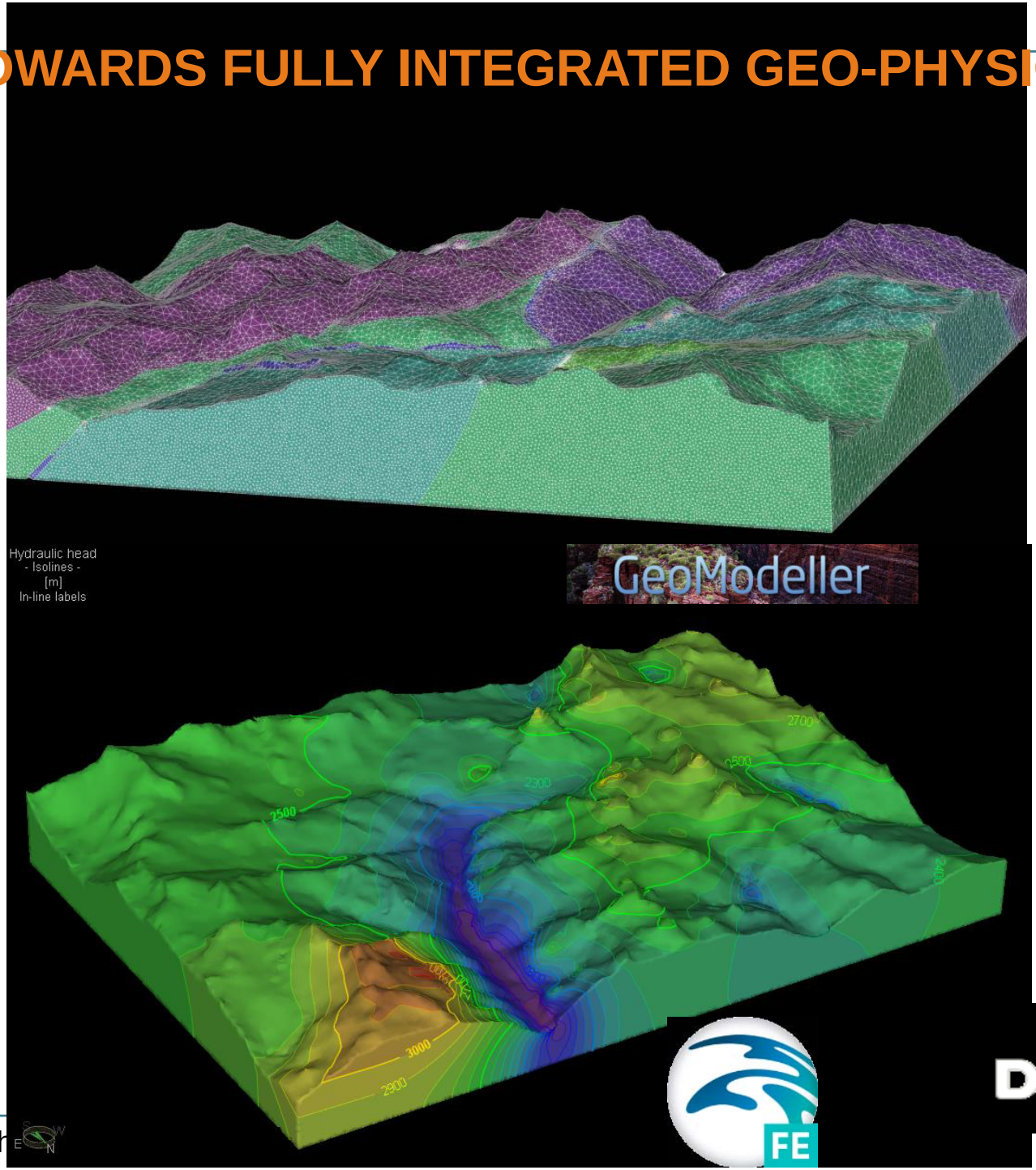


Ongoing research



Very thin stratigraphic bias: mesh size control (minimum size , maximum size) different size criteria for different units are required for seismic simulations.

TOWARDS FULLY INTEGRATED GEO-PHYSICAL MODELS



Geomodeller

Feflow

INTREPID GEOPHYSICS

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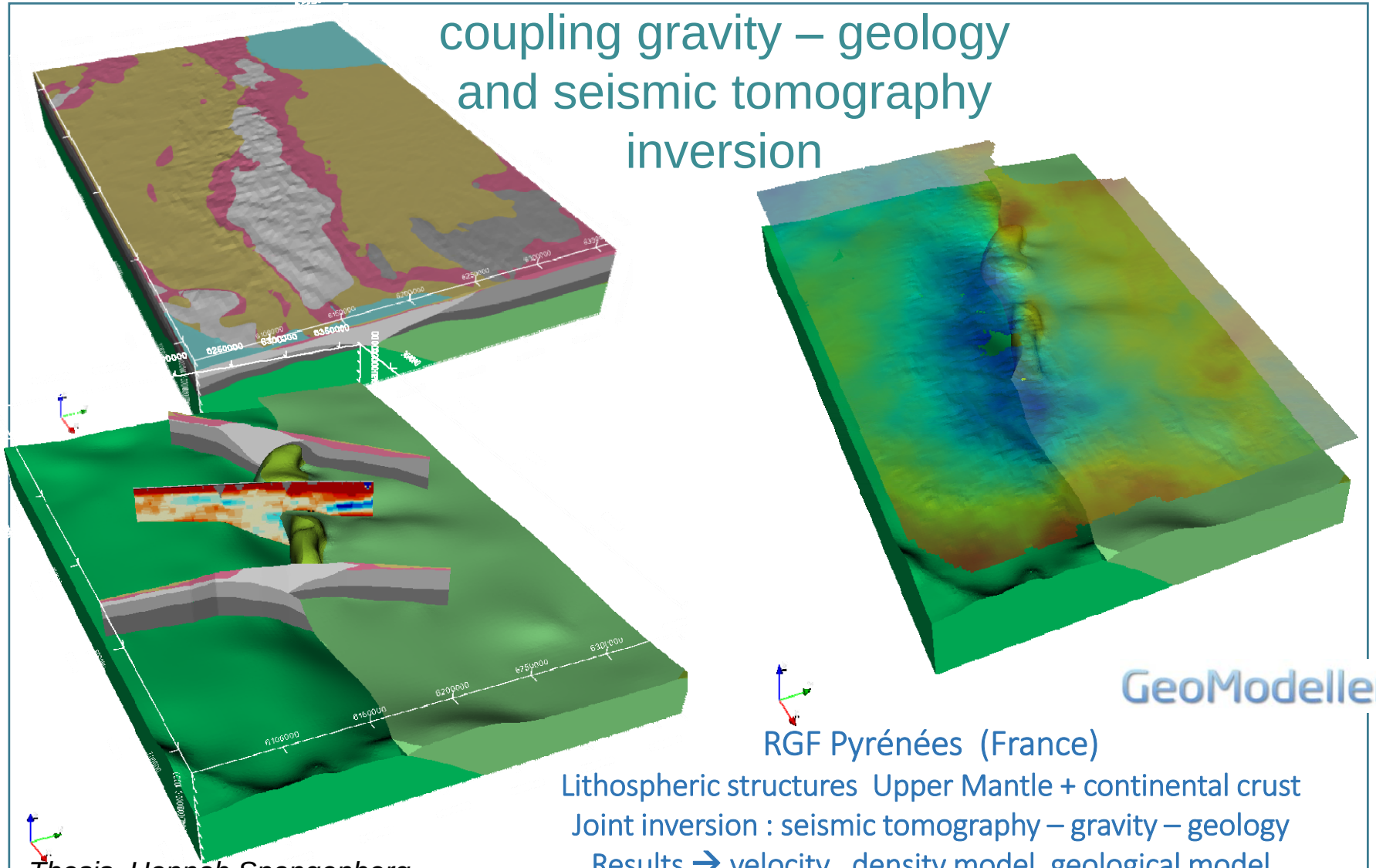
DHI WASY

FE

coupling gravity – geology and seismic tomography inversion



GeoModeller

RGF Pyrénées (France)

Lithospheric structures Upper Mantle + continental crust

Joint inversion : seismic tomography – gravity – geology

Results → velocity , density model, geological model

Thesis Hannah Spangenberg

Collaboration with "Observatoire Midi Pyrénées, Toulouse University»

Conclusions

This is research that we (try to) push on our daily survey production work.

The challenge is to make these developments easily available for every-day practice
→ integration into existing software

→ We are in the process of integrations of all these developments
around a modelling library (open-source ?)
(see lopez et al. poster session)

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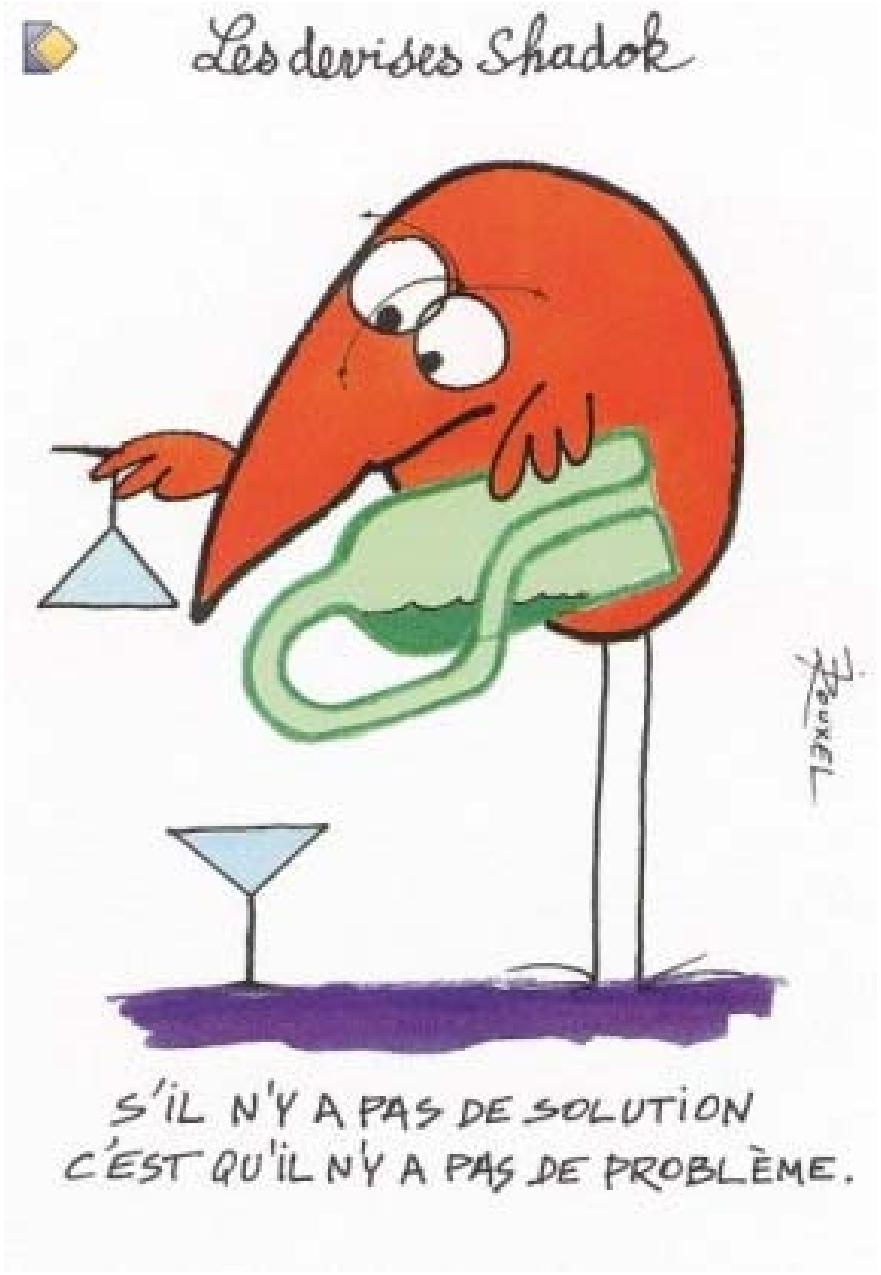
Les devises Shadok
S'IL N'Y A PAS DE SOLUTION
C'EST QU'IL N'Y A PAS DE PROBLÈME.