Scientific visualization with Python

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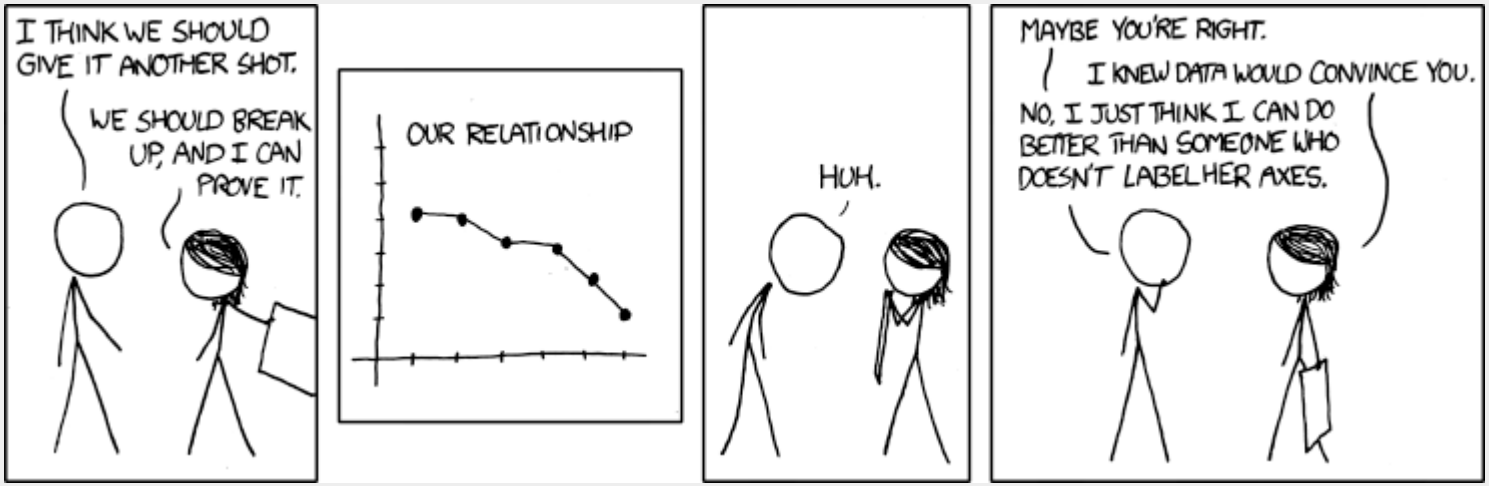
Download the material!!

https://github.com/nicoguaro/scivis_tutorial_pycon2019



https://xkcd.com/833/

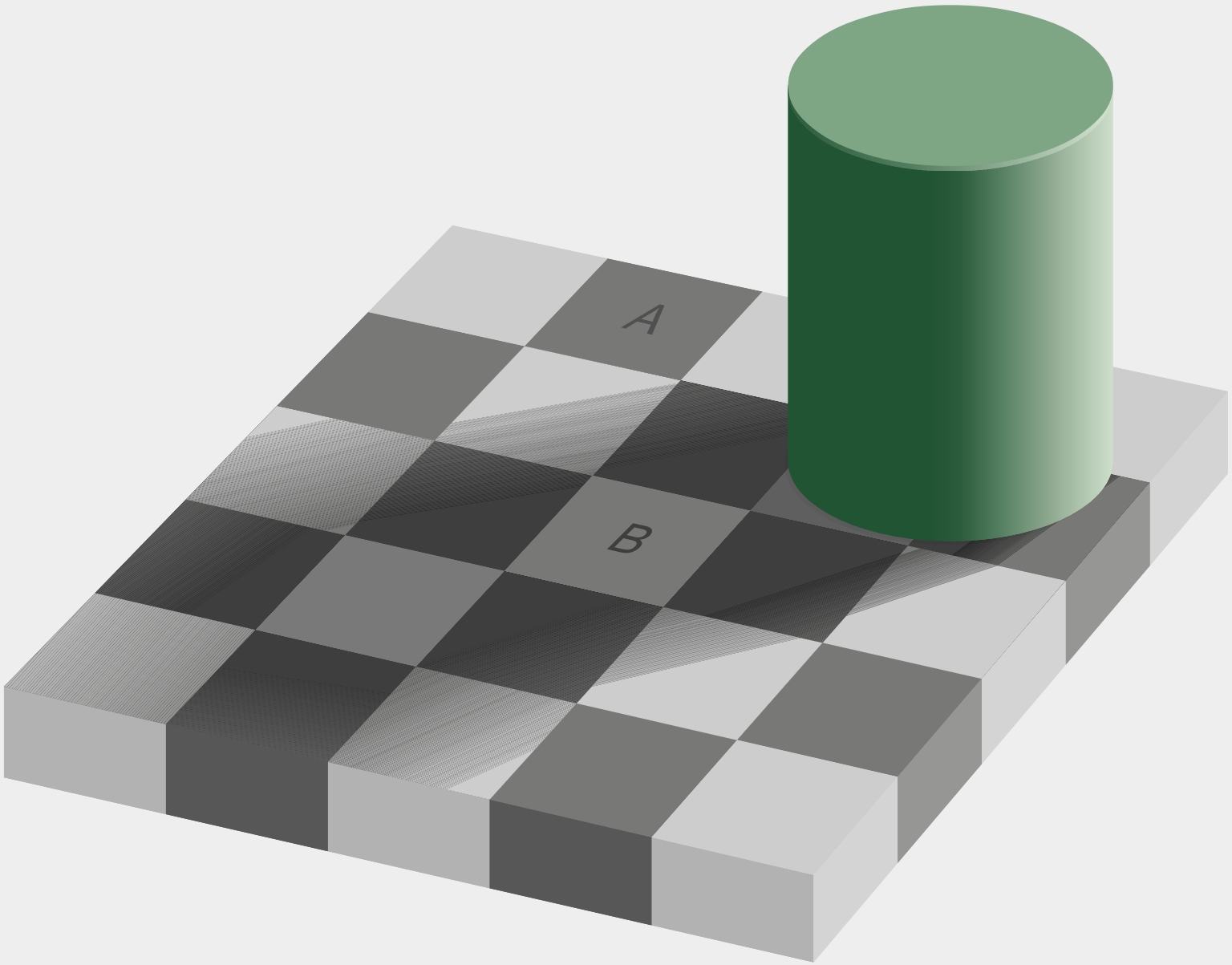
What is visualization?

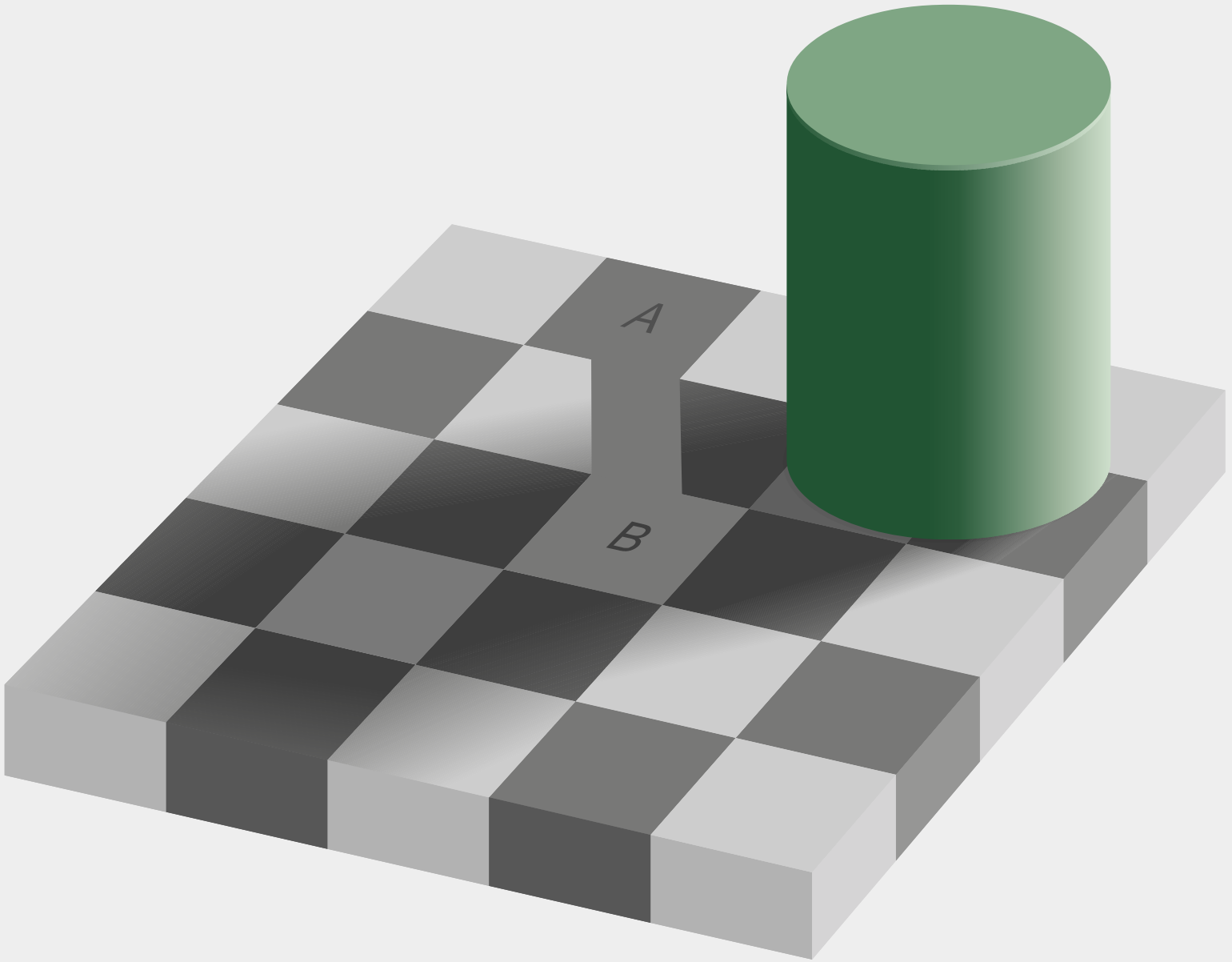
Definition

Visualization: communication of information using graphic representations.

It is multidisciplinary

- Computer graphics
- Numerical analysis
- Digital image/signal processing
- Scientific computing
- Art and design
- Psychophysics


A
B


A
B

Why visualizing?

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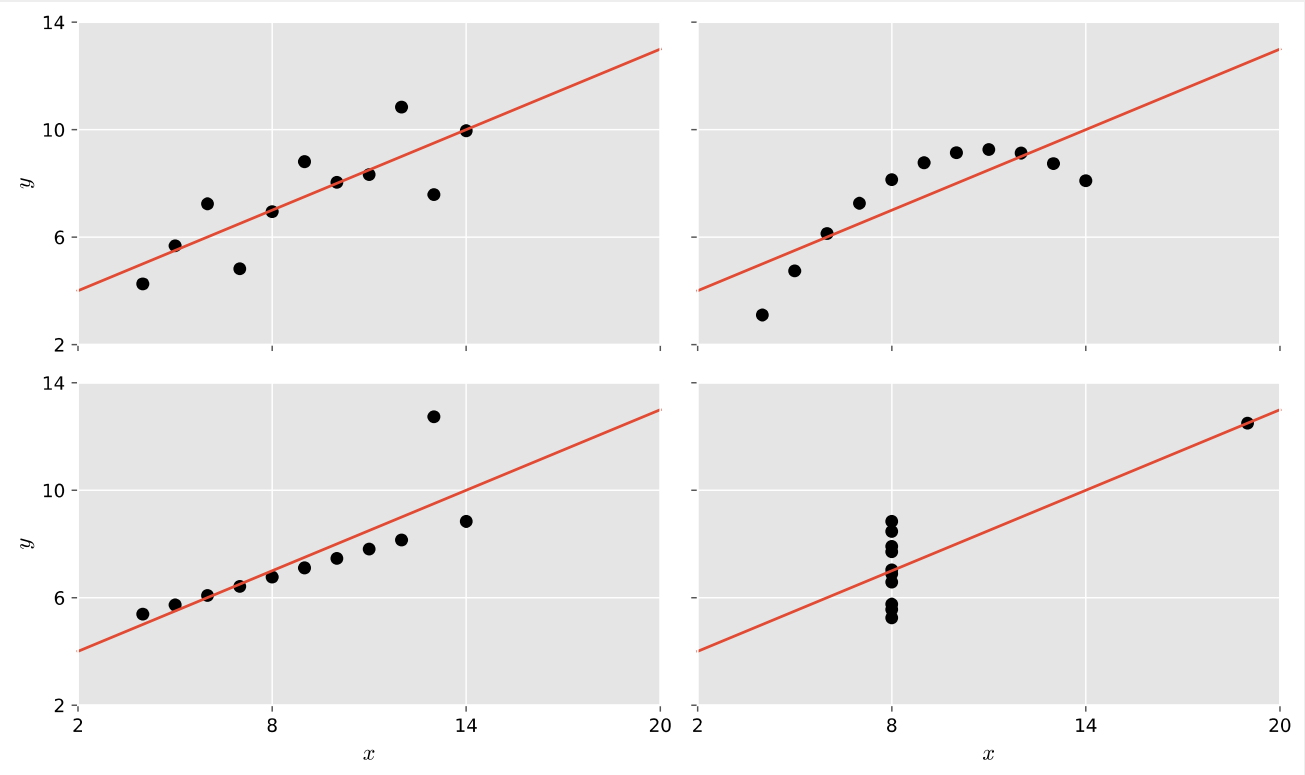
This image presents the same information but associating a gray-scale to the numbers.

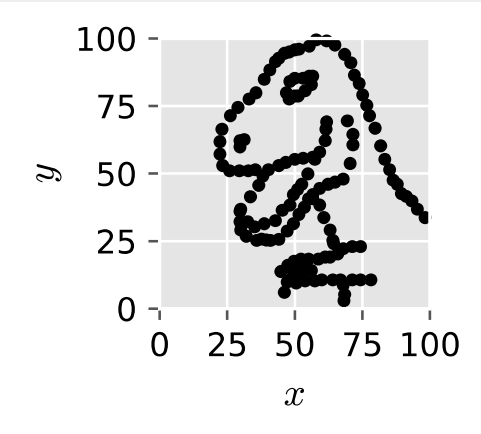
Anscombe quartet

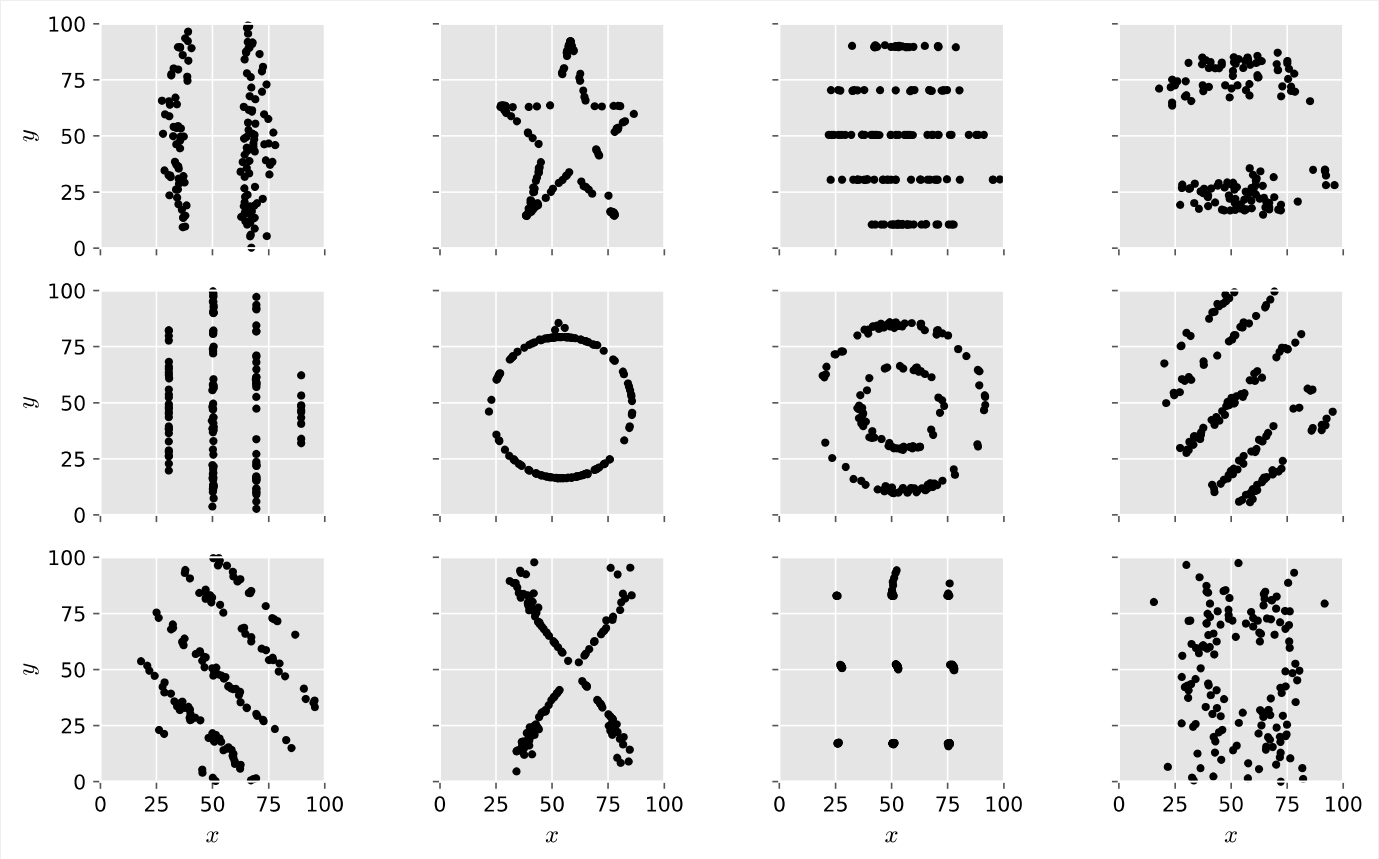


Francis Anscombe (1973). Graphs in statistical analysis. American Statistician, 27, 17-21.

Property	Value
Mean for each x variable	9.0
Variance for each x variable	11.0
Mean for each y variable	7.5
Variance for each y variable	4.12
Correlation coefficient between x and y	0.816
Linear regression	$y = 3 + 0.5\,x$

Datasaurus dozen





Matejka et al.
"Same stats,
different graphs"
ACM, 2017.

Property	Value
Mean for each x variable	54.26
Variance for each x variable	16.76
Mean for each y variable	47.83
Variance for each y variable	26.93
Correlation coefficient between x and y	-0.06

Exploratory vs explanatory visualization

Exploratory vs. explanatory analysis

We can divide the visualization pipeline in two stages:

- Exploratory analysis; and
- Explanatory analysis.

These two stages do not follow the same needs and are not (necessarily) done using the same tools.

Exploratory visualization

Exploratory visualization is a key process in the scientific inquiry, since it helps us in the understanding of phenomena. The data might come from experiments or simulations.

Exploratory visualization

In exploratory analysis it is key to have GUI to interact with our software in a manual fashion. Nevertheless, we also need automation (using scripts, for example) in order to have a reproducible pipeline. These two needs creates a trade-off, and it might help us selecting the tools that work for us.

Explanatory visualization

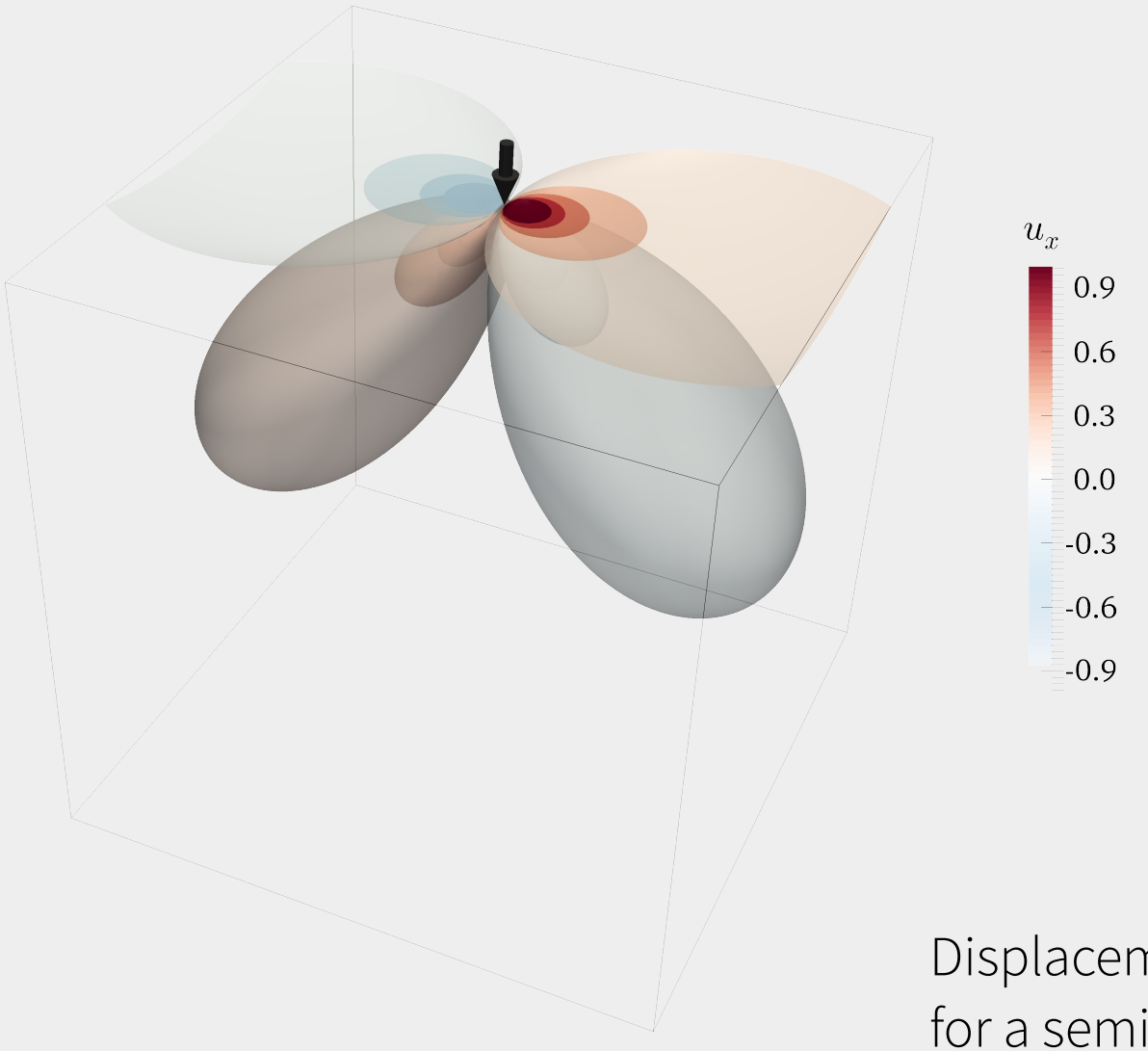
Explanatory visualization focus on communication, that is, in presenting the information to the public. The context of this might be on a conference, paper or class.

In this workshop we focus on **exploratory** visualization.

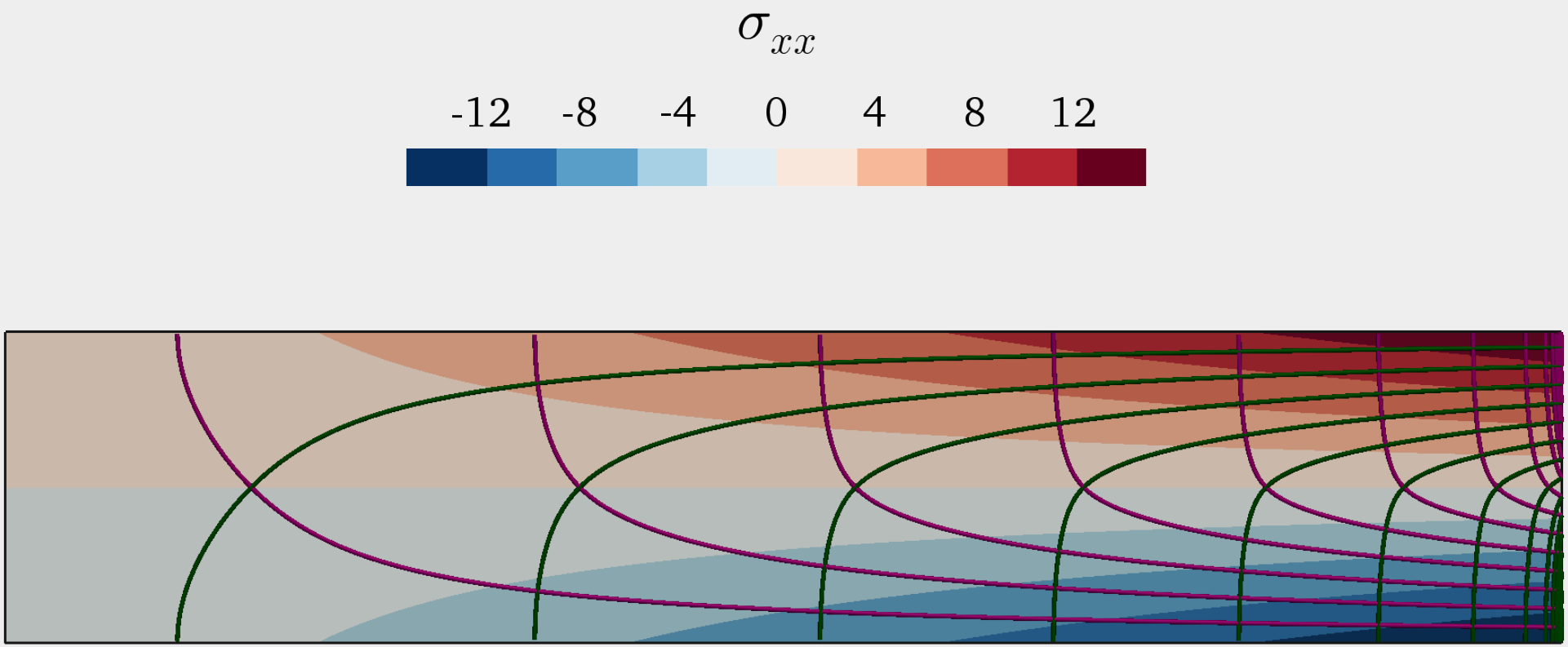
Spatial data visualization

Spatial visualization

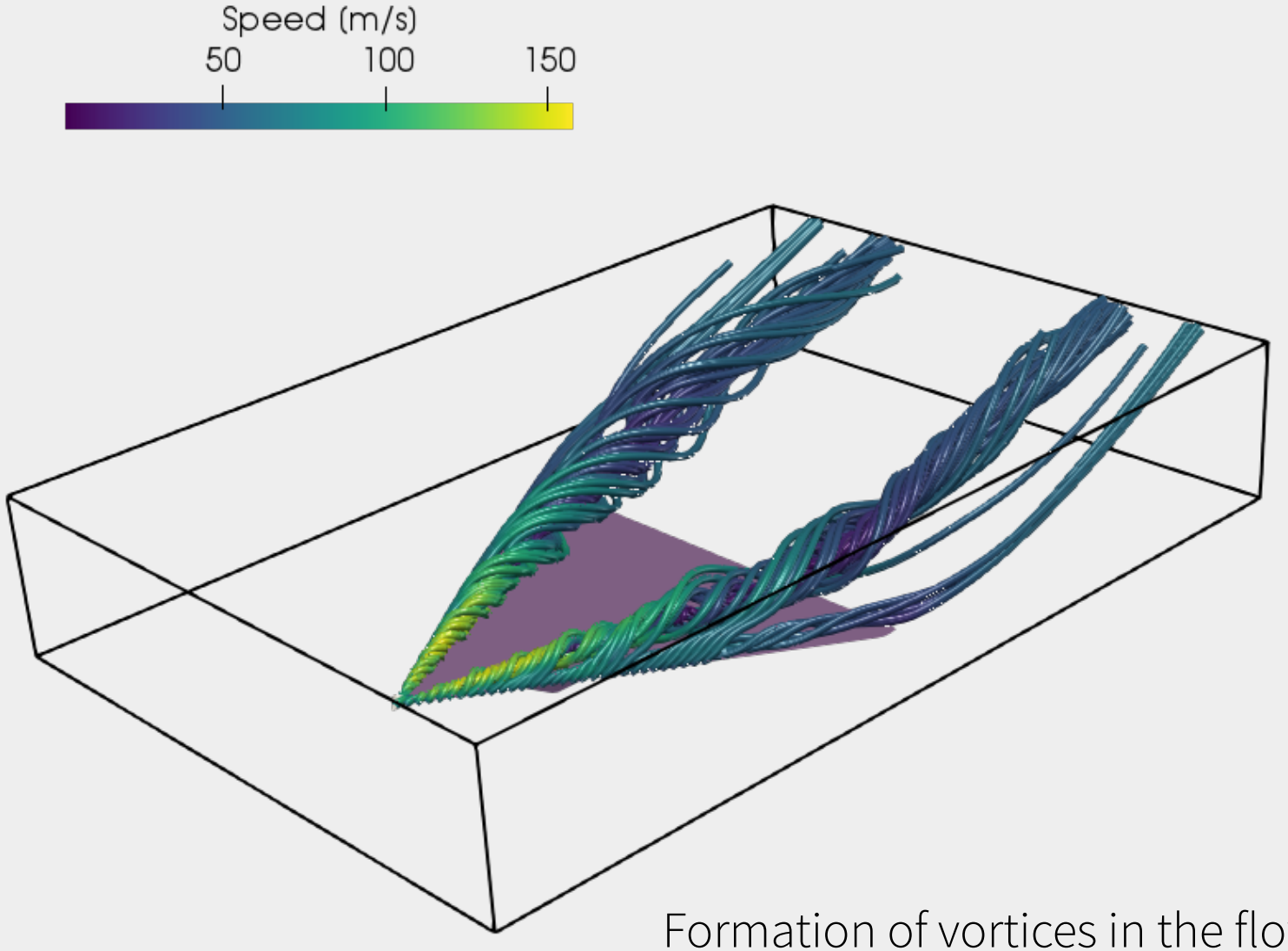
It corresponds to the field of scientific visualization and assumes data have space-time explicit or implicit attributes.



Displacement in the *x* direction for a semi-infinite medium with a point load applied on the surface.



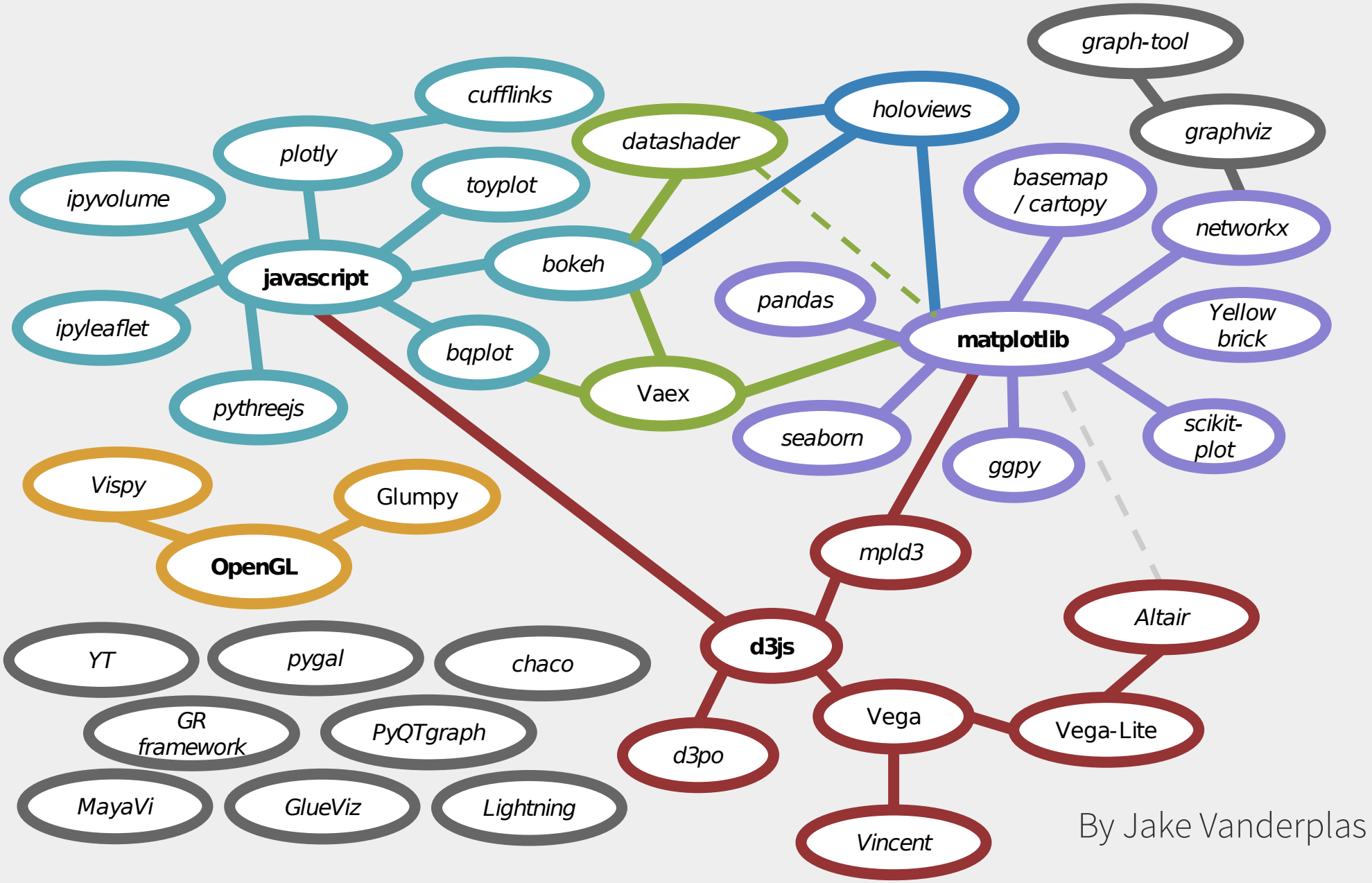
Horizontal stress in a cantilever beam. The lines represent direction of maximum/minimum stress.



Formation of vortices in the flow around a delta wing.

Visualization ecosystem in Python

Python's Visualization Landscape



By Jake Vanderplas

Python's Visualization Landscape

I highly recommend to watch the talk by Jake Vanderplas about this topic:

> Jake Vanderplas (2017). Python Visualization Landscape, PyCon 2017

Available in the following link:

> https://youtu.be/FytuB8nFHPQ

Spatial data visualization in Python

Packages for spatial data visualization

Although, there are much fewer packages for spatial data visualization in Python, there are still plenty of them.

Spatial data visualization with Python

- Matplotlib
- yt
- ipyvolume
- Glumpy

- VTK
- MayaVi
- vtki

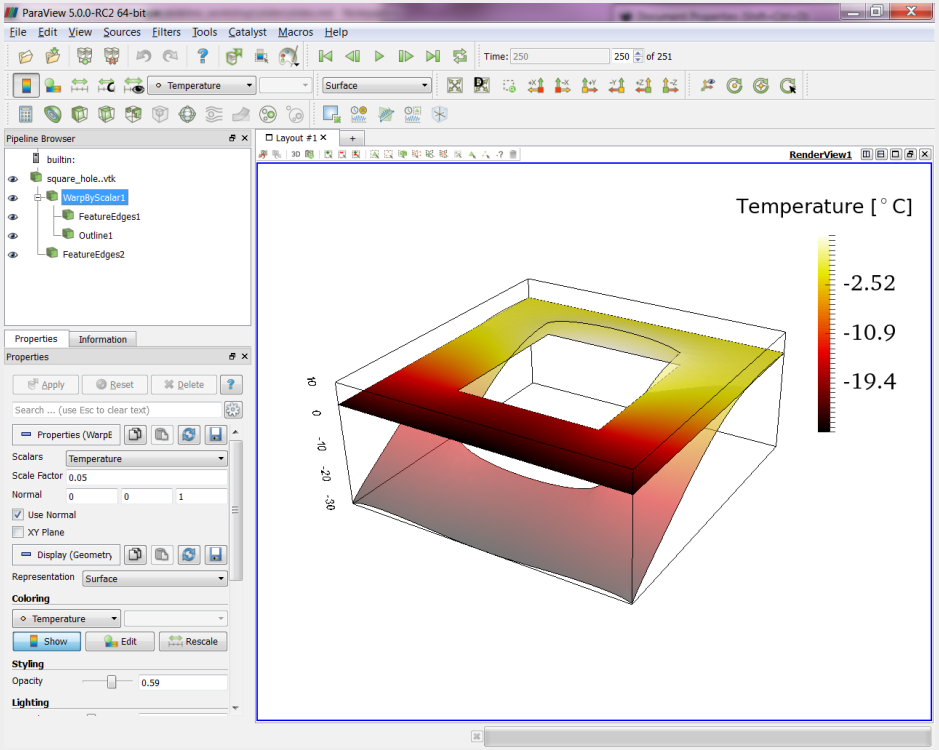
Spatial data visualization with Python

From the previous list, Glumpy and VTK would be the ones that provide more versatility. Nevertheless, this comes with the price of not being user-friendly.

ParaView as an alternative

ParaView is an open source multiple-platform application for interactive, scientific visualization.

Everything that is done in the user interface can be recorded as a Python script.



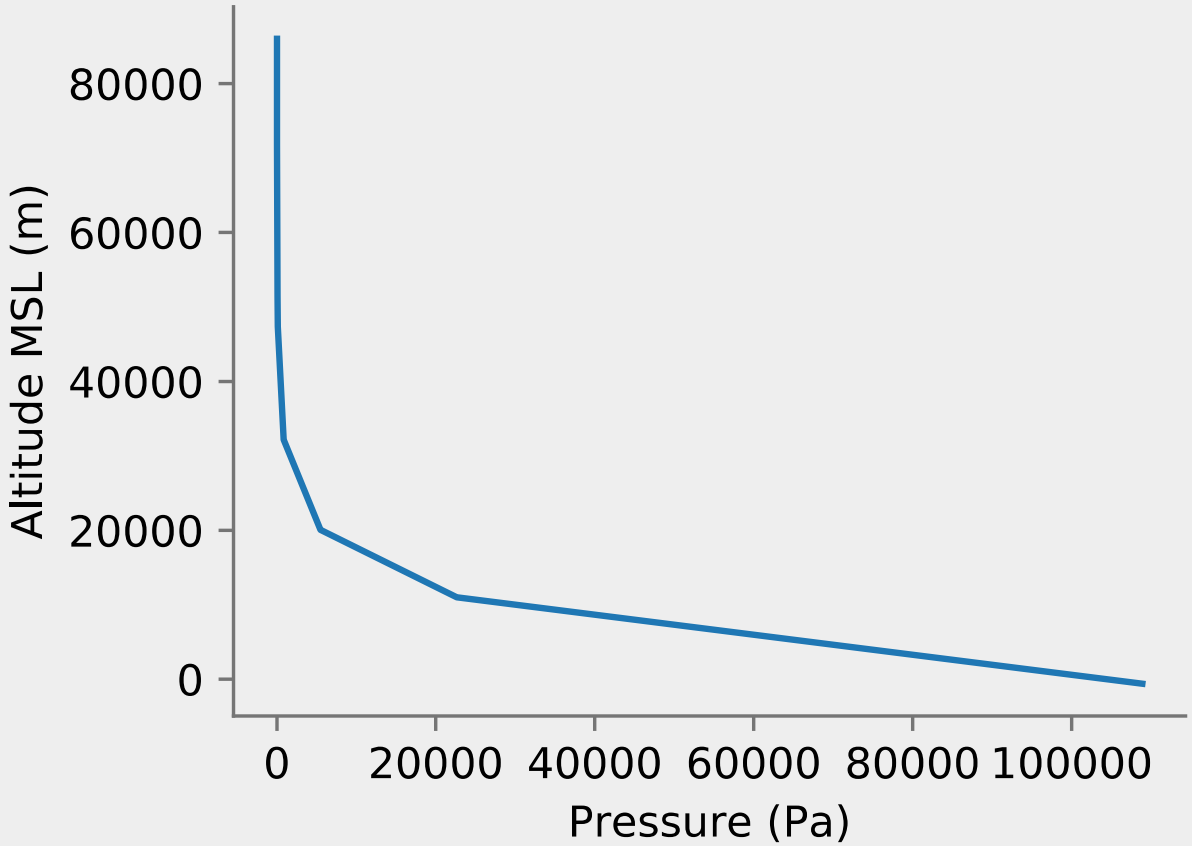
Examples

From low to high dimensionality …

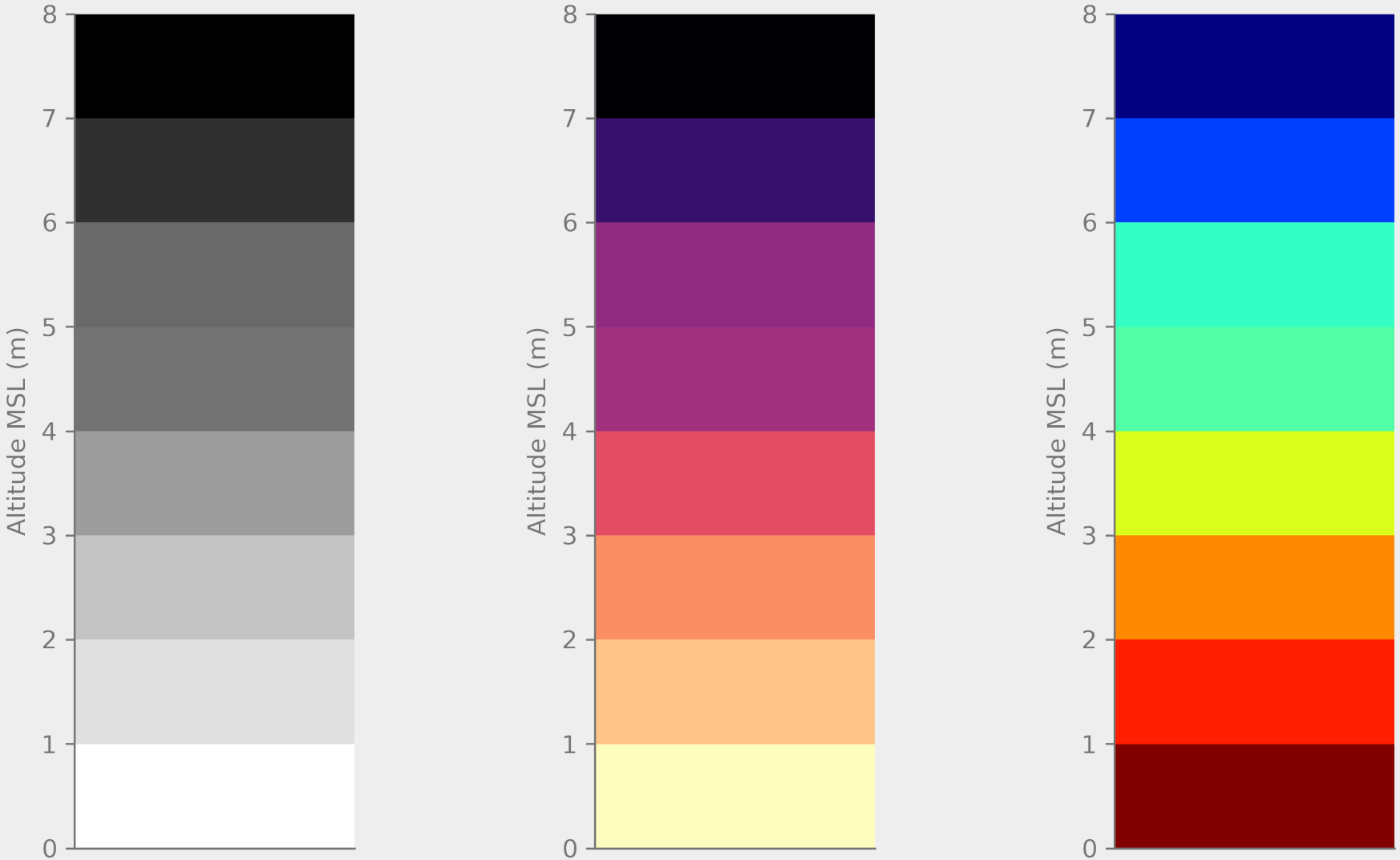
Let’s consider an order assuming that the visualization of lower dimensions can be used to present projections or subsections from data with higher dimensionality.

Data in one dimension

Spatial data in one dimension is usually the result of accumulating measurements along some trajectory in space.



Pressure vs altitude: line graph as a sequence of values.



Pressure vs altitude: colormap used to represent a sequence of values.

Data in two dimensions

For data in two dimensions it is common to associate the dimensions of the data to the dimension on a screen (or display).

Some common options are:

- Image
- Deformed surface
- Dispersion graph
- Map
- Isocontours

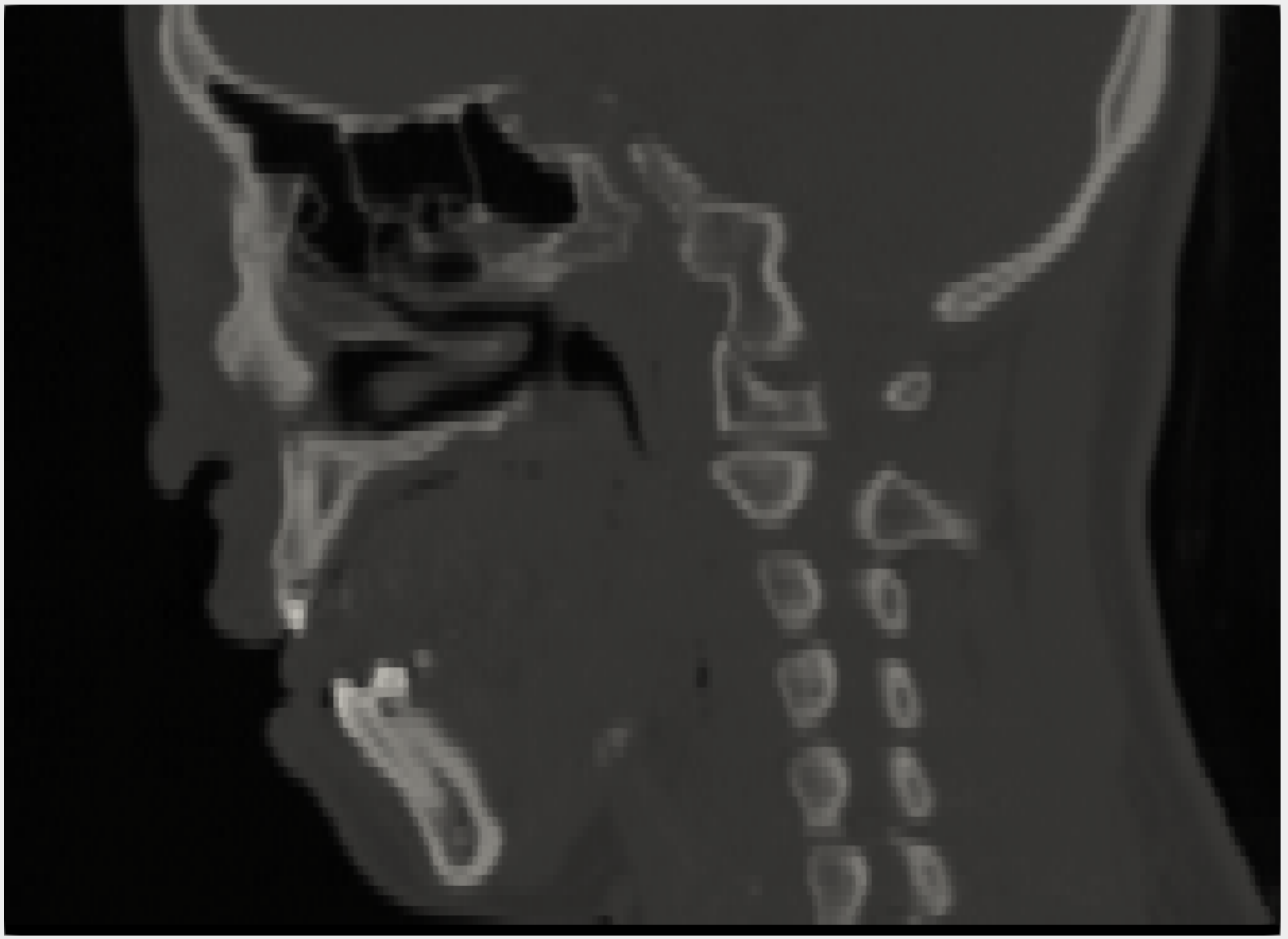
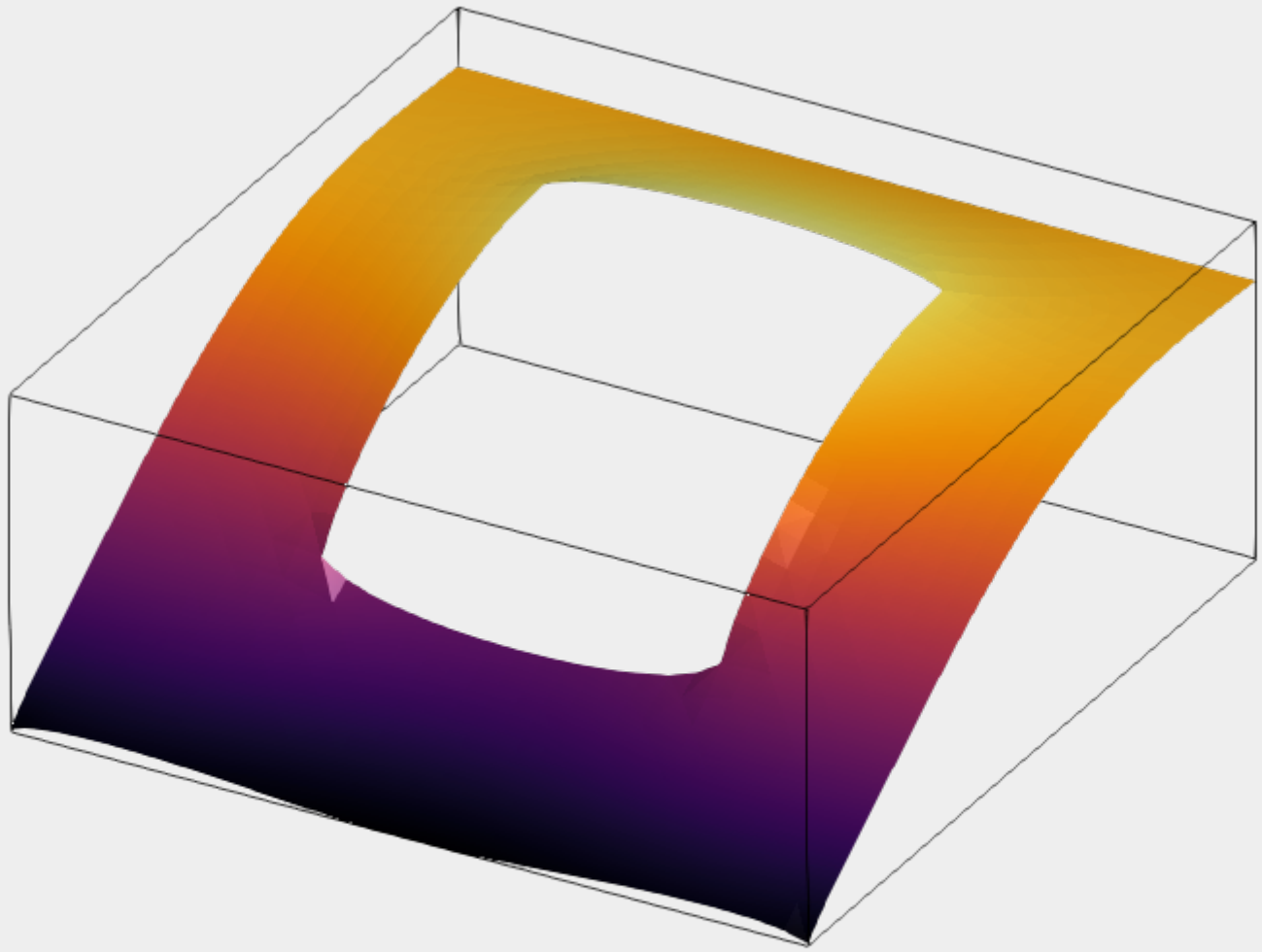
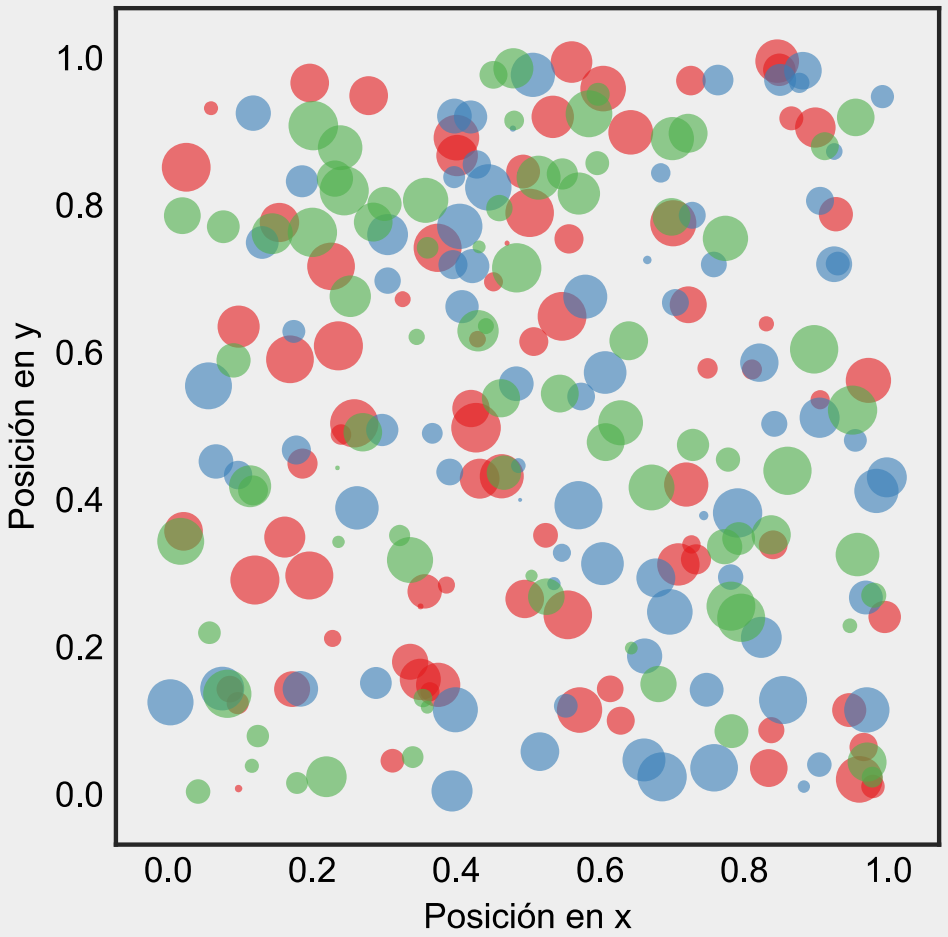


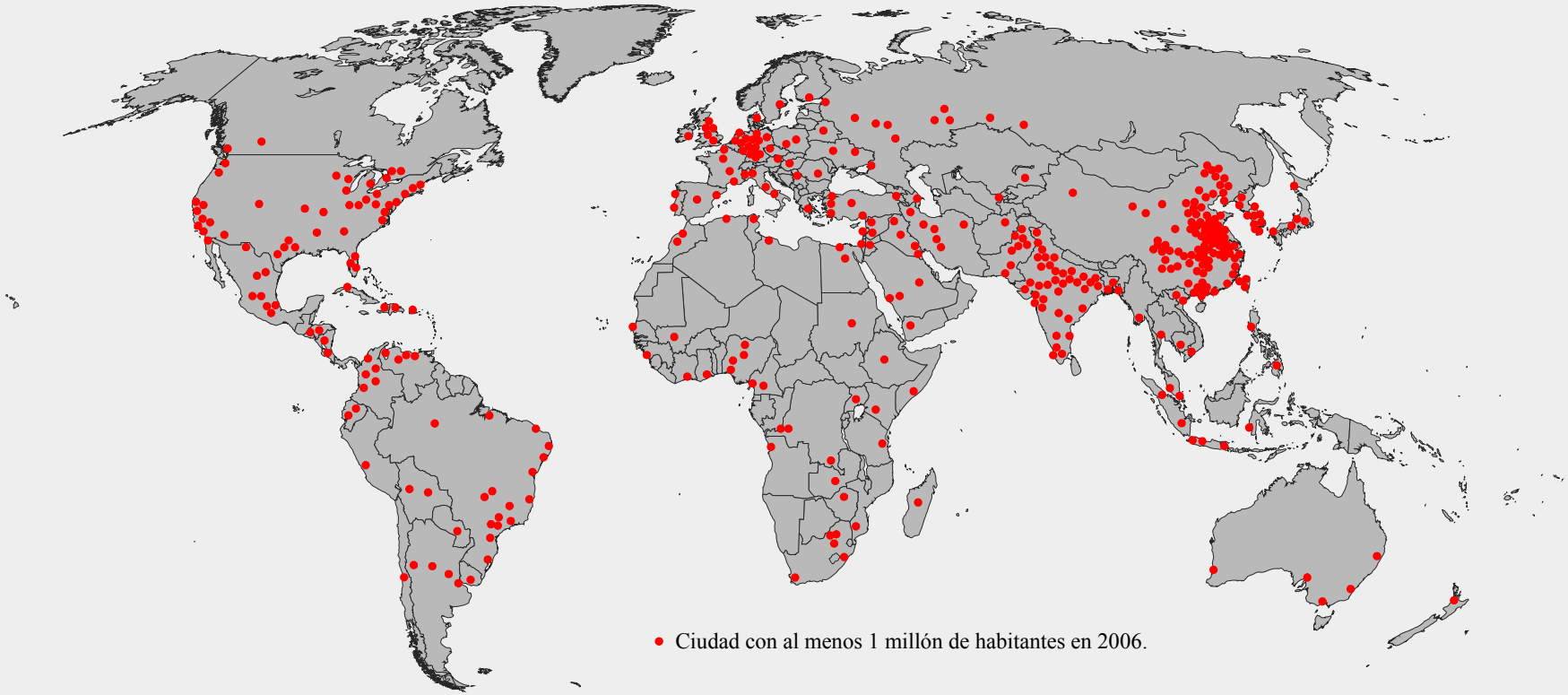
Image from a dataset from a tomography.

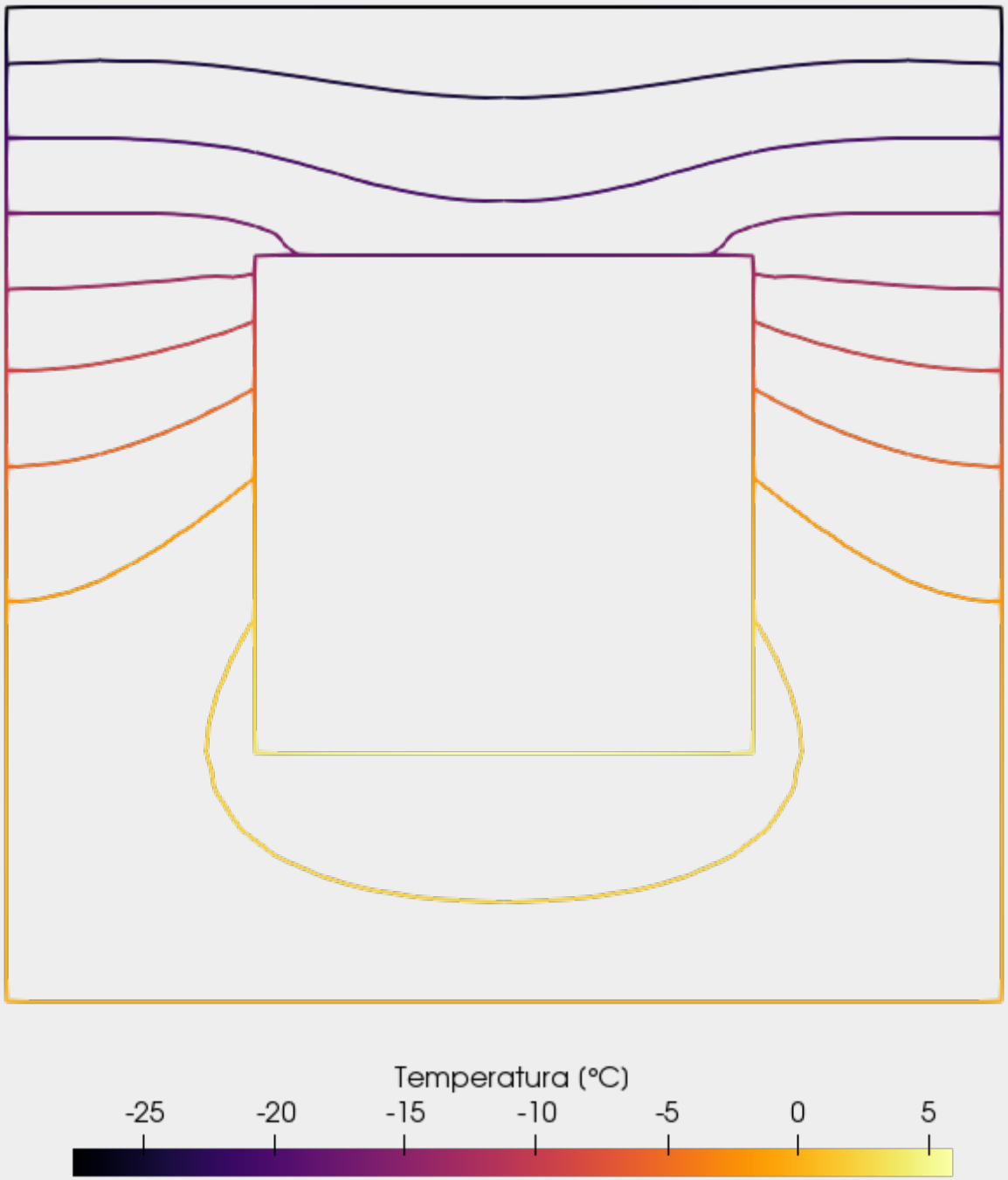


Temperature in a plate with a square hole: example with a deformed surface.



Location of particles with different sizes and types. Notice that we are not interpolating the values.


Ciudad con al menos 1 millón de habitantes en 2006.



Temperature in a plate with a square hole: example of isocontours.

Data in three dimensions

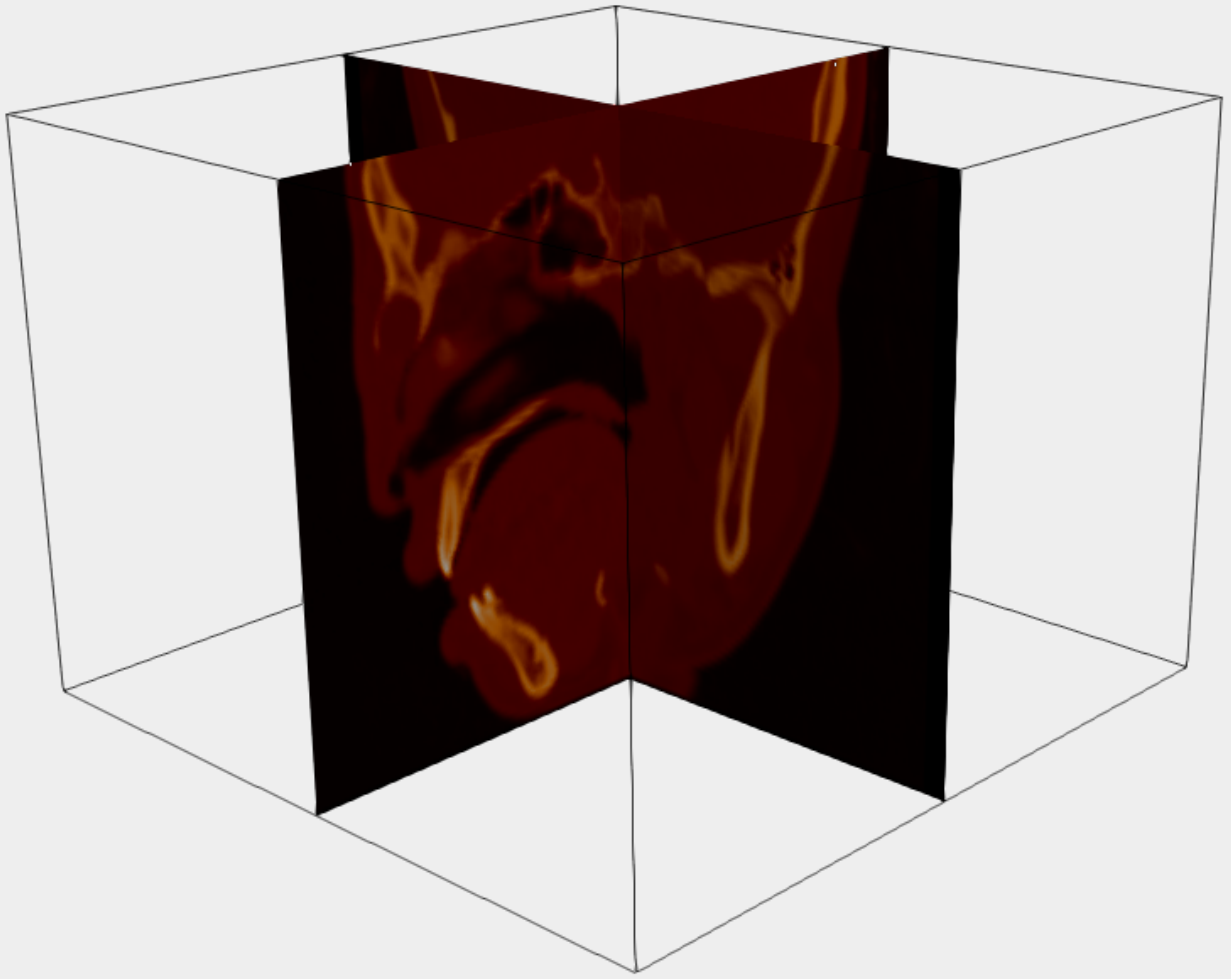
As in two dimensions, data in three dimensions represent continuous or discrete "phenomena".

In three dimensions there is a problem that does not exist in 2D: our objects can obstruct the visibility of other objects in the scene.

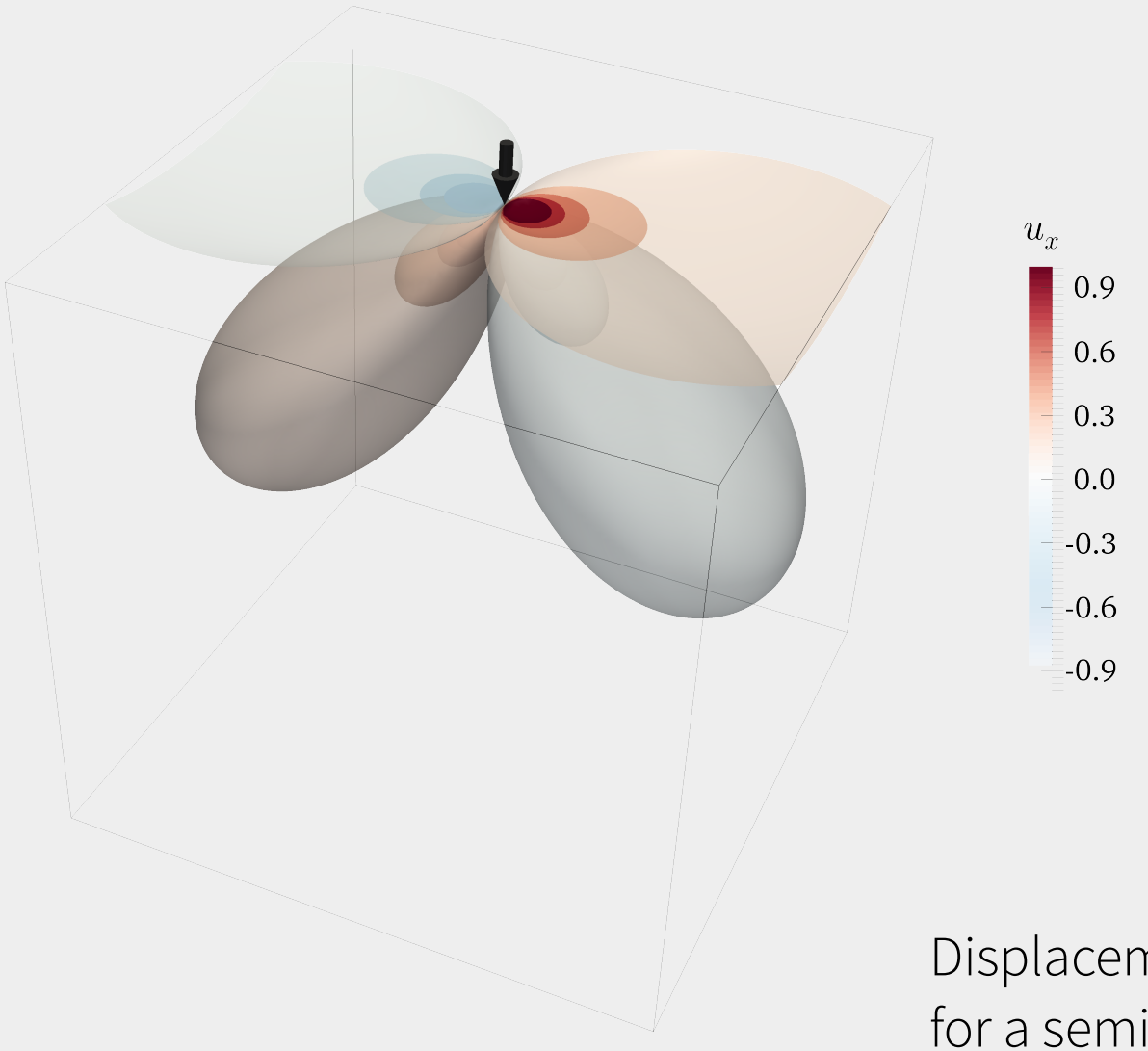
Visualizing volumetric data

Visualization of volumetric data use one of the following methods:

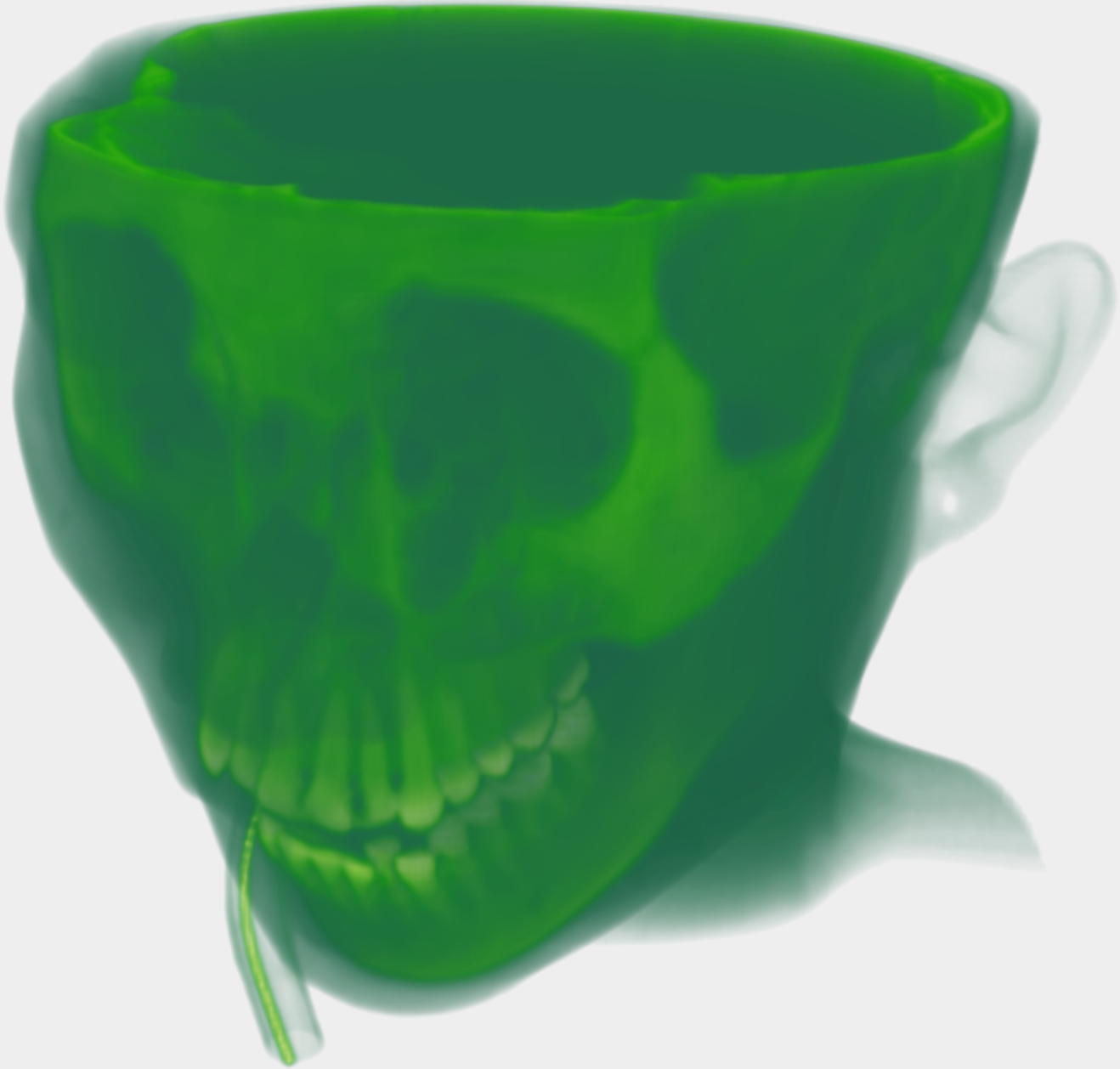
- Slicing
- Isosurfaces
- Volume rendering



Slices from a tomography dataset.



Displacement in the *x* direction for a semi-infinite medium with a point load applied on the surface.



Volume rendering of a tomography dataset.

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