

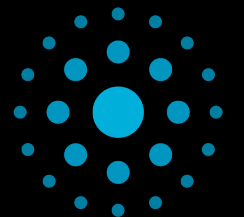
GEODYNAMIC MODELLING



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UNIVERSITÉ
CÔTE D'AZUR



GEODYNAMIC MODELLING

WITH **UNDERWORLD2**

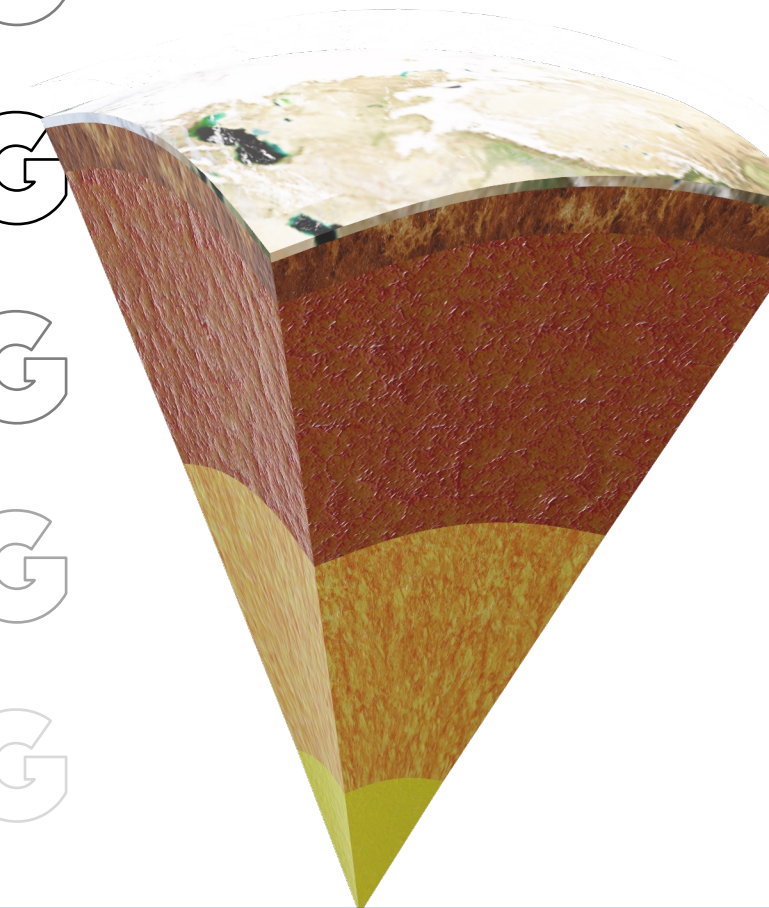
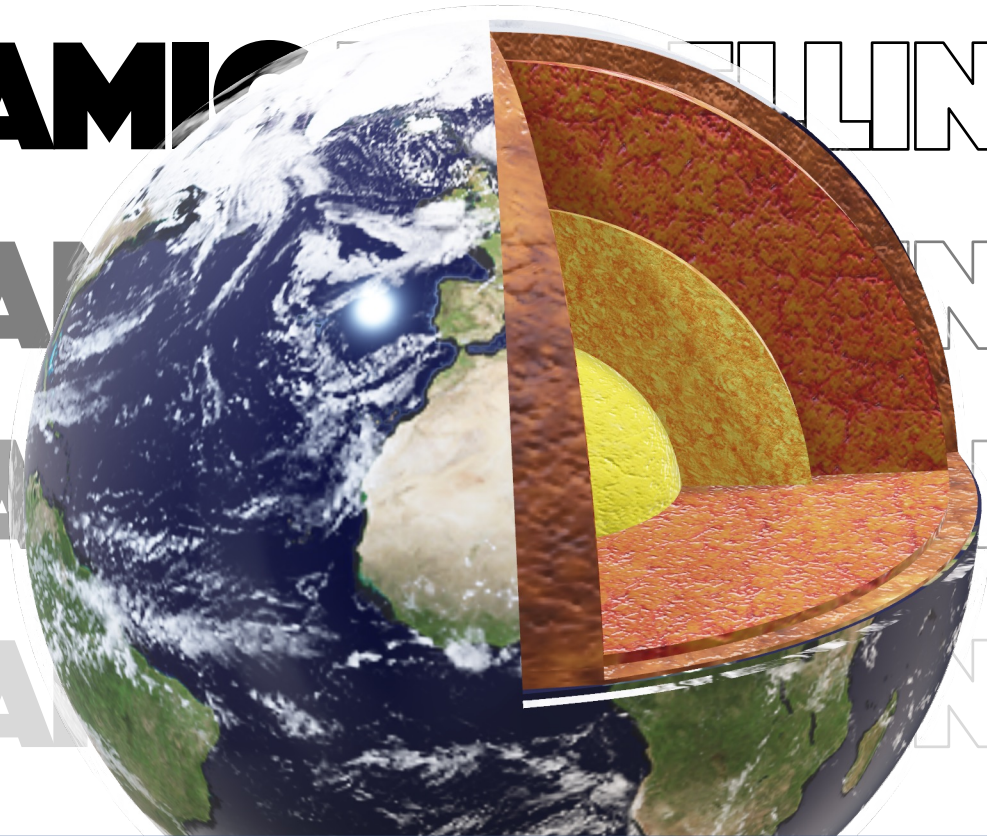
GEODYNAMIC MODELLING

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Where to start?

🏠 The Underworld Geodynamics Modelling Code

latest

Search docs

- Geodynamics
- Numerical Methods
- Installation
- User Guide
- UWGeodynamics
- Underworld API Reference
- UW2 Github
- UW2 Website
- UW2 Zenodo

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Underworld



Underworld2 is a Python API (Application Programming Interface) which provides functionality for the modelling of geodynamics processes, and is designed to work (almost) seamlessly across PC, cloud and HPC infrastructure. Primarily the API consists of a set of Python classes from which numerical geodynamics models may be constructed. The API also provides the tools required for inline analysis and data management. For scalability across multiprocessor platforms, MPI (Message Passing Interface) is leveraged, and for performant operation all heavy computations are executed within a statically typed layer.

<https://underworld2.readthedocs.io/en/latest/index.html>

UW2 Installation (comes in many flavours)

- <https://underworld2.readthedocs.io/en/latest/Installation.html>
- Choose an installation:
 - From `source` - *good luck!*
 - With `pip` (*package installer for Python*)
 - With `Docker`
 - **Linux** users should be able to install `docker` using the distribution's standard package manager <https://docs.docker.com/desktop/install/linux-install/>
 - **Windows** users should note that for **Windows 10 Home** you should install `Docker Toolbox` > <https://docs.bitnami.com/containers/how-to/install-docker-in-windows/>, while for **Windows 10 Professional** you should install `Docker Desktop` > <https://docs.docker.com/desktop/install/windows-install/>
 - **Apple OS X** users should use `Docker Desktop` > <https://docs.docker.com/desktop/install/mac-install/>

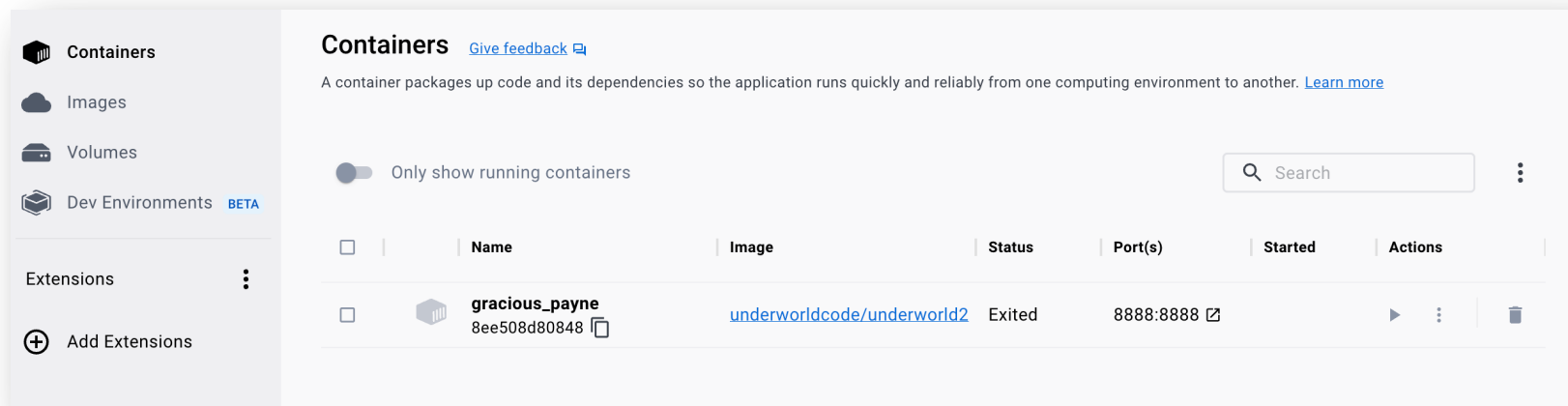
UW2 Installation (OS specific with Docker)

- Step by step guide:

1. Install **Docker Desktop** compatible with the OS on your local machine and open the application (*see previous page for OS specific installer links*)
2. Open a terminal and create a local folder `uw2023_kigali` in your home directory (`mkdir ~/uw2023_kigali`) and navigate to this folder in the terminal (`cd ~/uw2023_kigali`)
3. Run the following command in the terminal (install UW2 image and link the VM workspace volume to the local directory:

```
docker run -v $PWD:/home/jovyan/workspace -p 8888:8888  
underworldcode/underworld2
```

4. UW2 image is now installed in **Docker Desktop**



UW2 Installation (alternative using local files)

- Step by step guide:

1. Install **Docker Desktop** using the OS specific installer provided
2. Open a terminal and create a local folder `uw2023_kigali` in your home directory (`mkdir ~/uw2023_kigali`) and navigate to this folder in the terminal (`cd ~/uw2023_kigali`)

3. Run the following command in the terminal to load UW2 local copy into Docker:

```
docker load -i uw2023_Kigali.tar
```

4. Run the following command in the terminal (install UW2 image and link the VM workspace volume to the local directory:

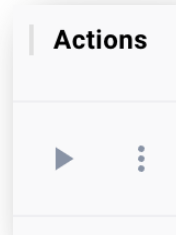
```
docker run -v $PWD:/home/jovyan/workspace -p 8888:8888  
underworldcode/underworld2
```







5. UW2 image is now installed in **Docker Desktop**

UW2 Installation (getting started)

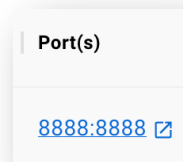
- Step by step guide:

- Start the container:



<input type="checkbox"/>	Name	Image	Status	Port(s)	Started	Actions
<input type="checkbox"/>	 gracious_payne 8ee508d80848 	underworldcode/underworld2	Running	8888:8888 	12 seconds ago	  

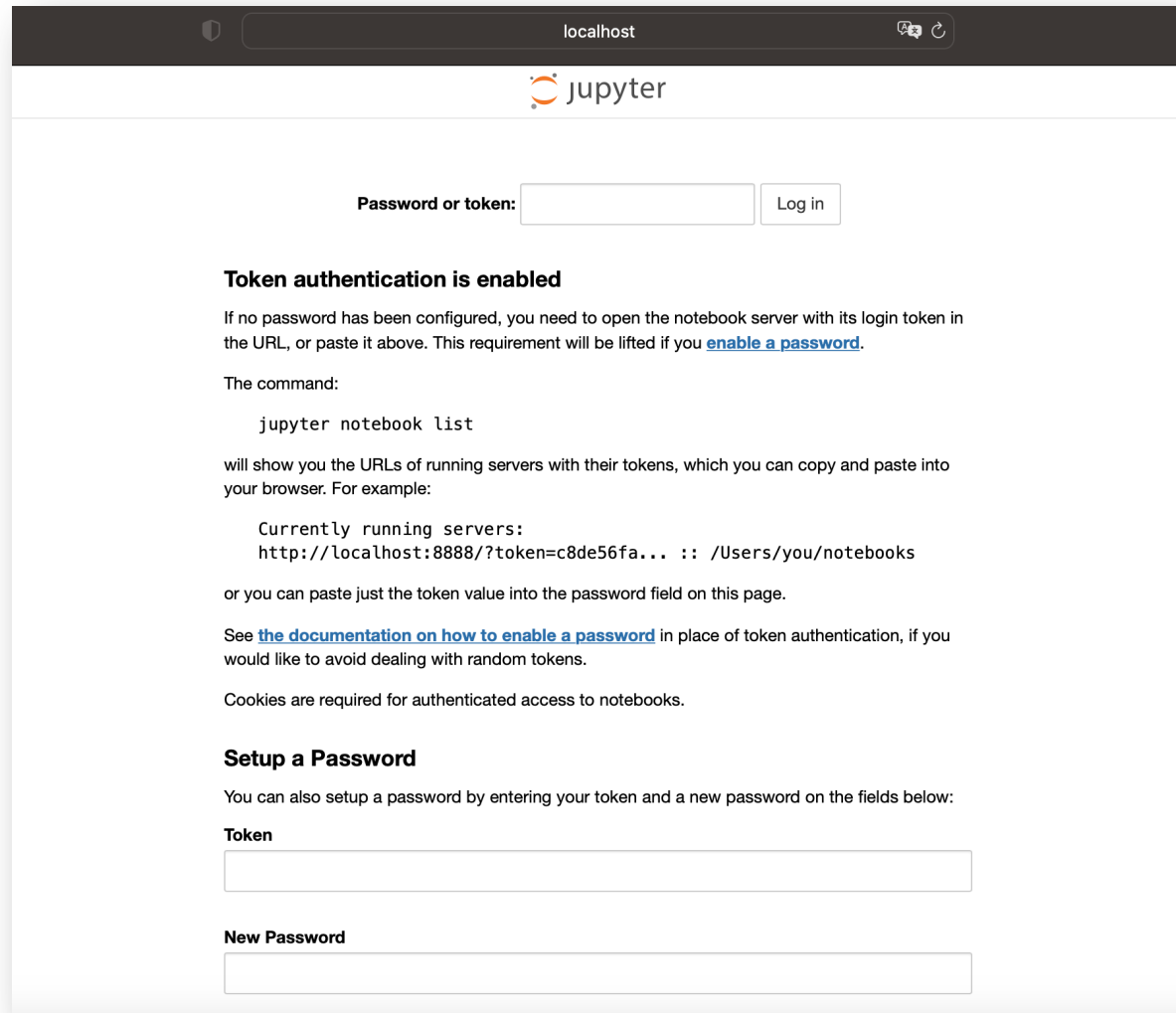
- And click the Port link:



- Your favourite browser window should be open

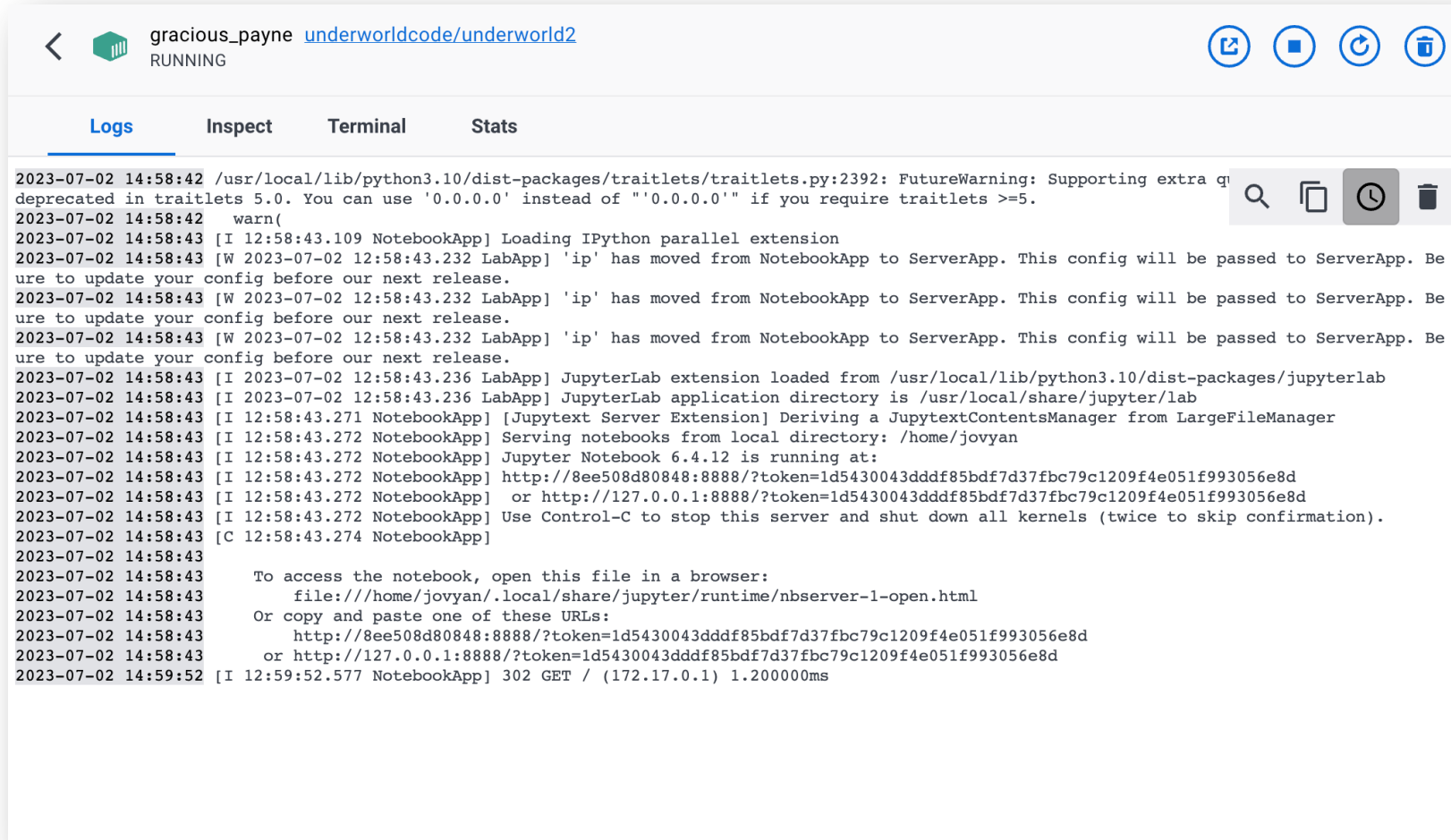
UW/2 Installation (getting started)

- Step by step guide:
 - Your favourite **browser** window should be open and requesting a **token**



UW2 Installation (getting started)

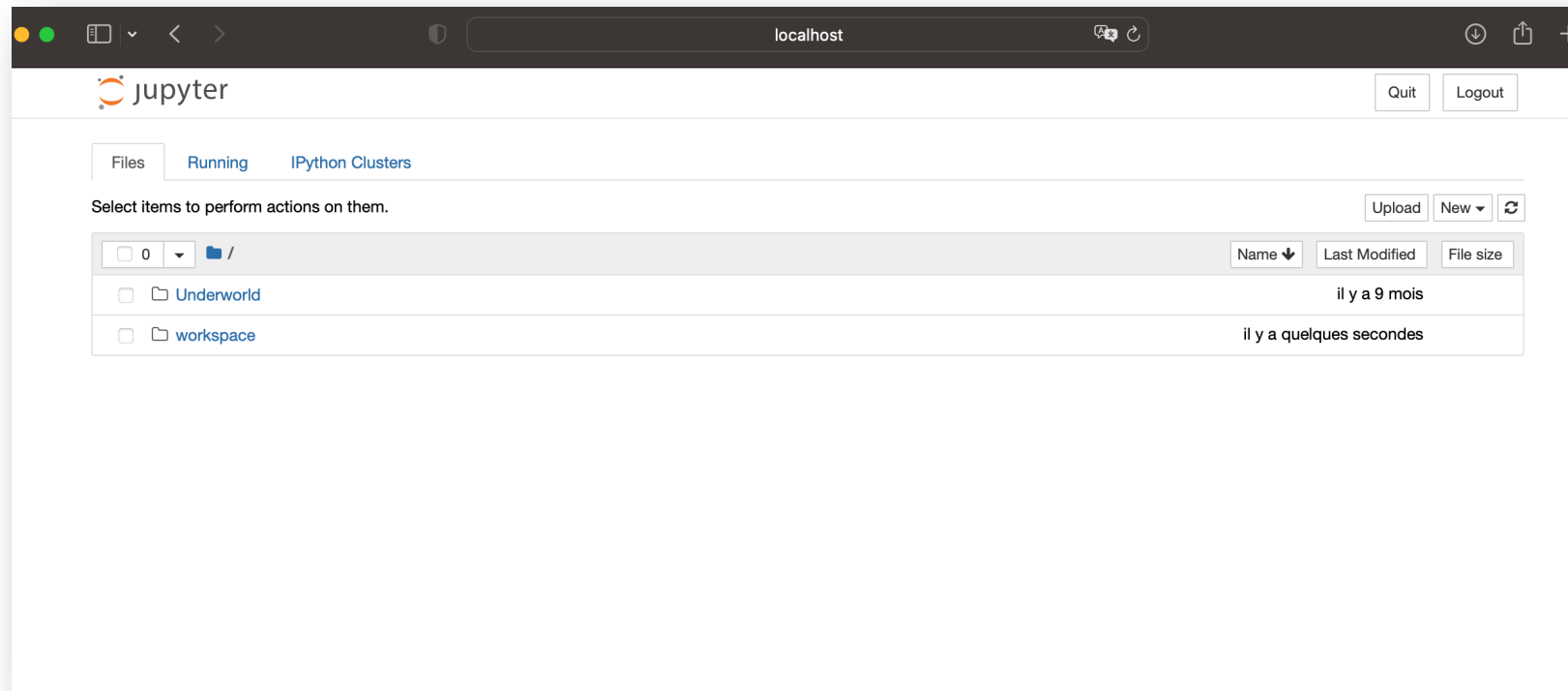
- Step by step guide:
 - Go back to [Docker Desktop Dashboard](#), inspect the Logs of the running container and copy the **token**, then paste it in your browser



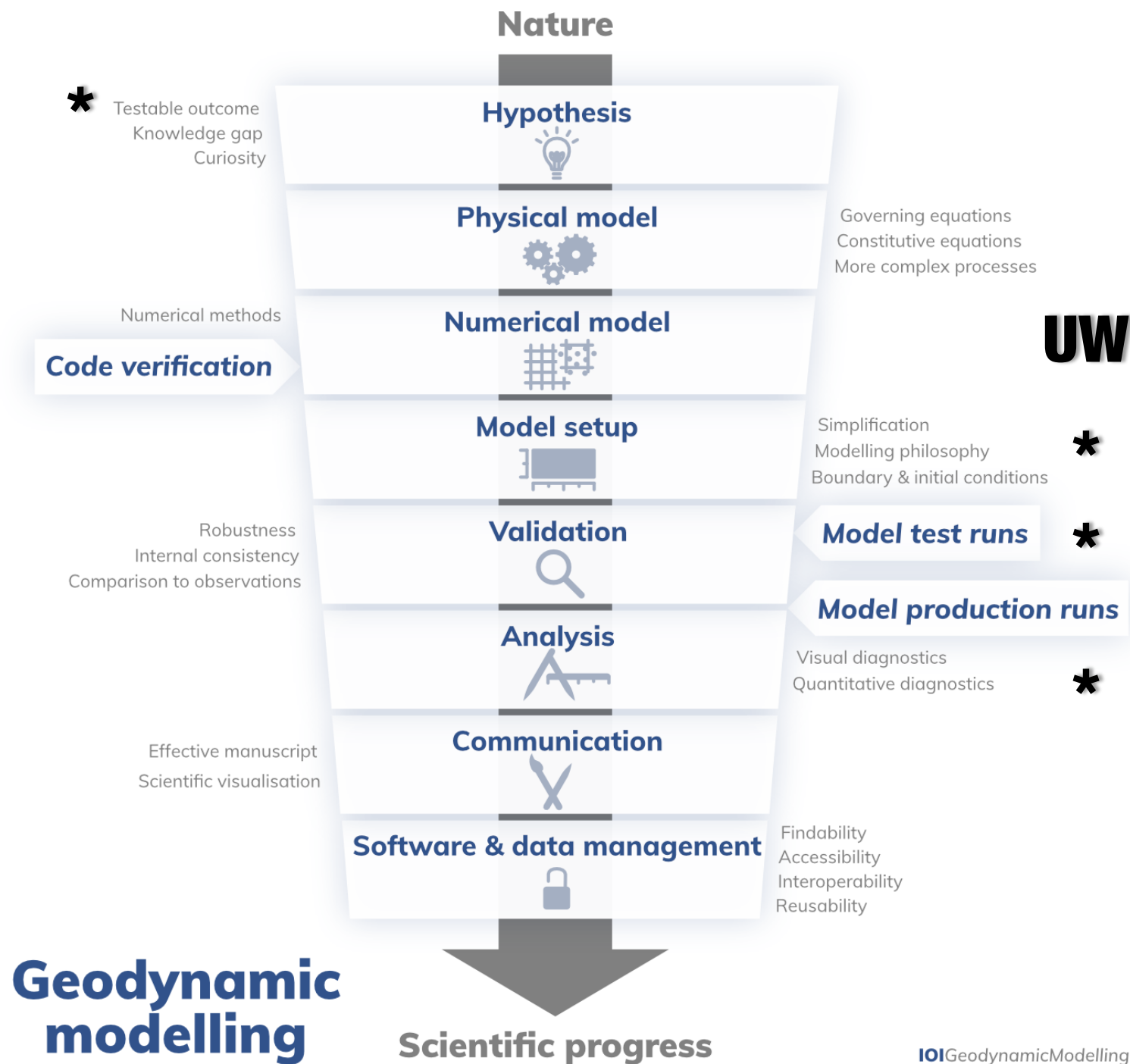
```
2023-07-02 14:58:42 /usr/local/lib/python3.10/dist-packages/traitlets/traitlets.py:2392: FutureWarning: Supporting extra q
deprecated in traitlets 5.0. You can use '0.0.0.0' instead of "'0.0.0.0'" if you require traitlets >=5.
2023-07-02 14:58:42 warn(
2023-07-02 14:58:43 [I 12:58:43.109 NotebookApp] Loading IPython parallel extension
2023-07-02 14:58:43 [W 2023-07-02 12:58:43.232 LabApp] 'ip' has moved from NotebookApp to ServerApp. This config will be passed to ServerApp. Be s
ure to update your config before our next release.
2023-07-02 14:58:43 [W 2023-07-02 12:58:43.232 LabApp] 'ip' has moved from NotebookApp to ServerApp. This config will be passed to ServerApp. Be s
ure to update your config before our next release.
2023-07-02 14:58:43 [W 2023-07-02 12:58:43.232 LabApp] 'ip' has moved from NotebookApp to ServerApp. This config will be passed to ServerApp. Be s
ure to update your config before our next release.
2023-07-02 14:58:43 [I 2023-07-02 12:58:43.236 LabApp] JupyterLab extension loaded from /usr/local/lib/python3.10/dist-packages/jupyterlab
2023-07-02 14:58:43 [I 2023-07-02 12:58:43.236 LabApp] JupyterLab application directory is /usr/local/share/jupyter/lab
2023-07-02 14:58:43 [I 12:58:43.271 NotebookApp] [Jupyter Server Extension] Deriving a JupyterTextContentsManager from LargeFileManager
2023-07-02 14:58:43 [I 12:58:43.272 NotebookApp] Serving notebooks from local directory: /home/jovyan
2023-07-02 14:58:43 [I 12:58:43.272 NotebookApp] Jupyter Notebook 6.4.12 is running at:
2023-07-02 14:58:43 [I 12:58:43.272 NotebookApp] http://8ee508d80848:8888/?token=1d5430043ddd85bdf7d37fbc79c1209f4e051f993056e8d
2023-07-02 14:58:43 [I 12:58:43.272 NotebookApp] or http://127.0.0.1:8888/?token=1d5430043ddd85bdf7d37fbc79c1209f4e051f993056e8d
2023-07-02 14:58:43 [I 12:58:43.272 NotebookApp] Use Control-C to stop this server and shut down all kernels (twice to skip confirmation).
2023-07-02 14:58:43 [C 12:58:43.274 NotebookApp]
2023-07-02 14:58:43
2023-07-02 14:58:43 To access the notebook, open this file in a browser:
2023-07-02 14:58:43 file:///home/jovyan/.local/share/jupyter/runtime/nbserver-1-open.html
2023-07-02 14:58:43 Or copy and paste one of these URLs:
2023-07-02 14:58:43 http://8ee508d80848:8888/?token=1d5430043ddd85bdf7d37fbc79c1209f4e051f993056e8d
2023-07-02 14:58:43 or http://127.0.0.1:8888/?token=1d5430043ddd85bdf7d37fbc79c1209f4e051f993056e8d
2023-07-02 14:59:52 [I 12:59:52.577 NotebookApp] 302 GET / (172.17.0.1) 1.200000ms
```

UW2 Installation (ready to model)

- Step by step guide:
 - You have installed UW2 on your machine and can almost start modelling!



- Copy [copy_UW_to_workspace.ipynb](#) in your workspace, move it to the root of the container in your browser, and execute the cells



Conservation equations

Rheology

Viscous	Elastic	Brittle

Mass

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0$$

Local changes in mass over time Influx/outflux of mass

Momentum

$$\nabla \cdot \boldsymbol{\sigma} + \rho \mathbf{g} = 0$$

Surface forces per unit volume Body forces per unit volume (gravity)

Energy

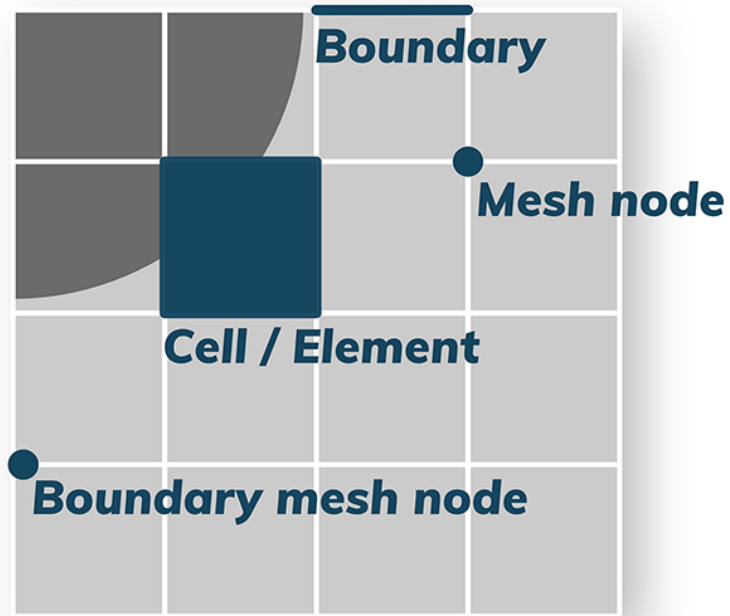
$$\rho C_p \left(\frac{\partial T}{\partial t} + \mathbf{v} \cdot \nabla T \right) - \nabla \cdot (k \nabla T) = \rho H + S$$

Changes in thermal energy over time Advection Conduction Internal heat production Other heating processes

UW2 Numerical Discretisation

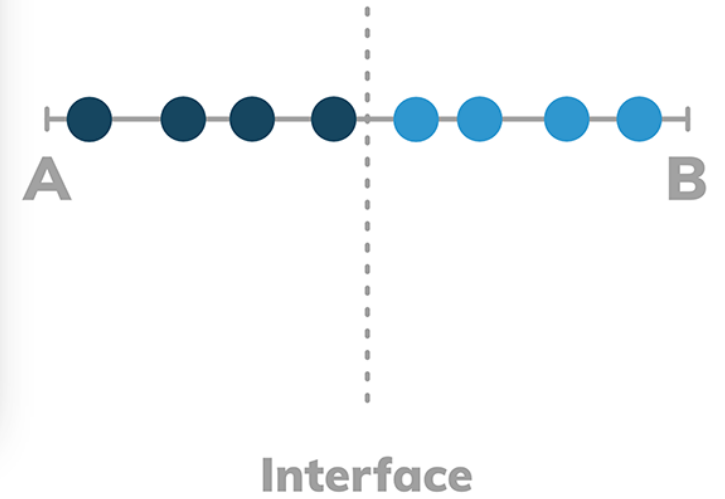
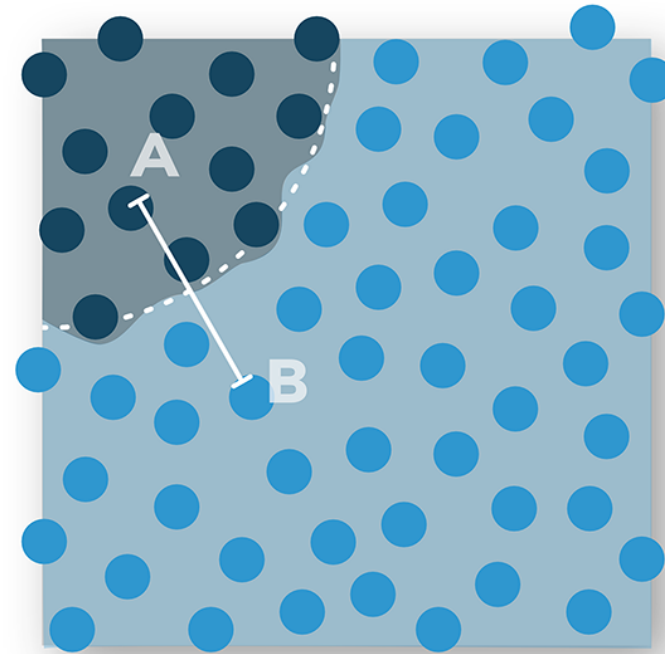
UW2: Finite Element code → Material Point Method

Domain

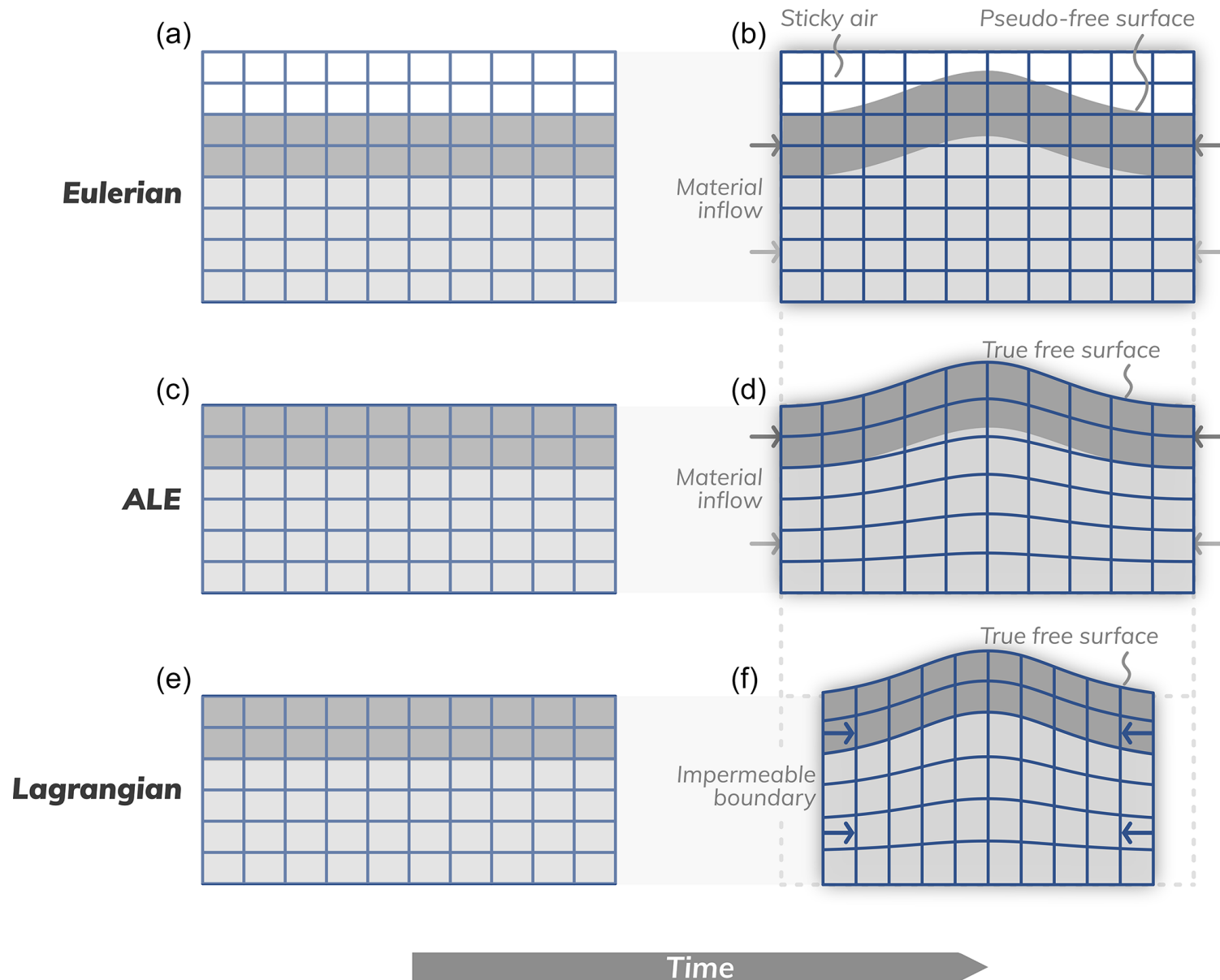


Material

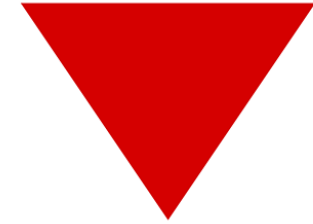
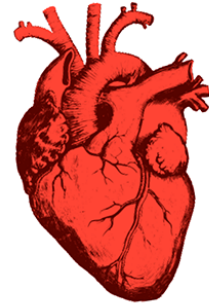
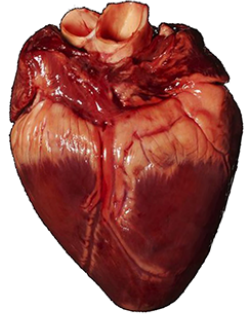
Particle-in-cell method



Kinematical descriptions



(a)



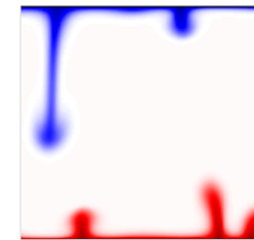
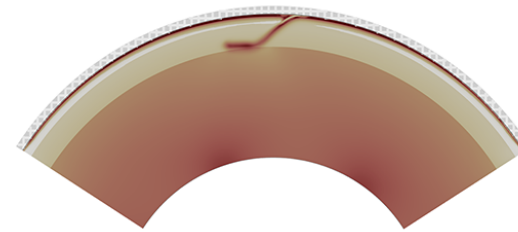
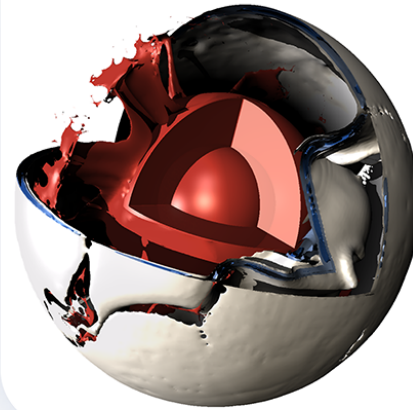
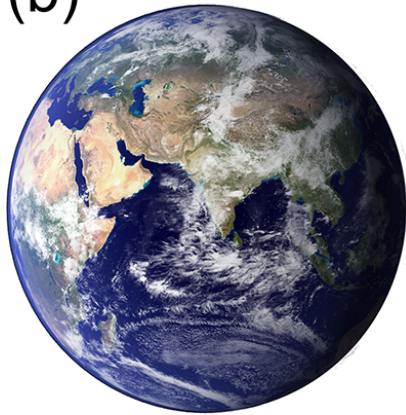
Nature

complex

Models

simple

(b)



Model complexity

	complex	Model	simple
Physical complexities	Reproduce	*Parameterise	Neglect
Multiphysics	Coupling	One-way coupling	None
Constitutive equations	Non-linear	Linearised	Constant
Domain geometry	3-D Spherical Wide	2-D	1-D Cartesian Narrow
Model duration	Time-dependent		Instantaneous
Initial conditions	Heterogeneous		Homogeneous
Boundary conditions	Free		Fixed
External forcing	Self-consistent		Imposed

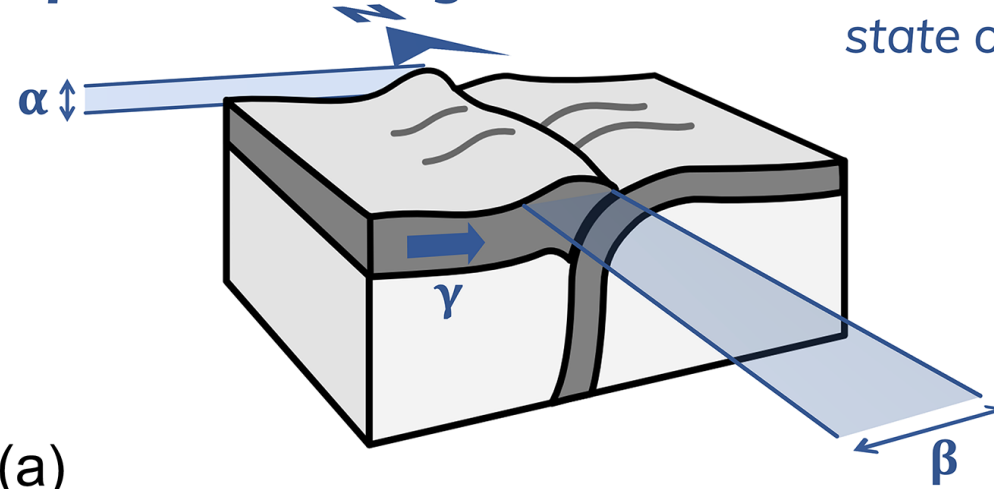
*Mimic a physical complexity with a simplified approach

Simplifying

Philosophies

Specific modelling

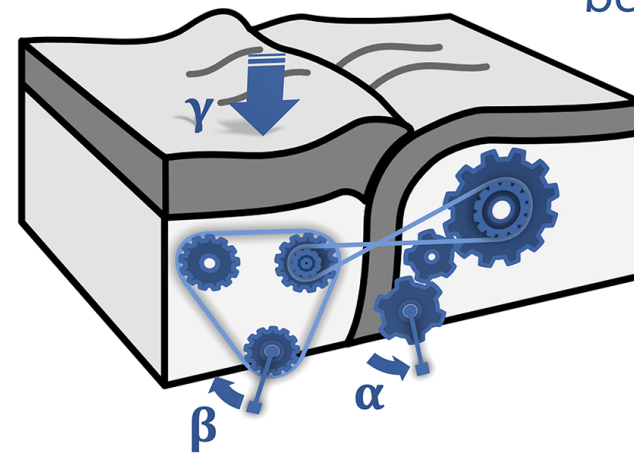
What causes the specific state of a system?



(a)

Generic modelling

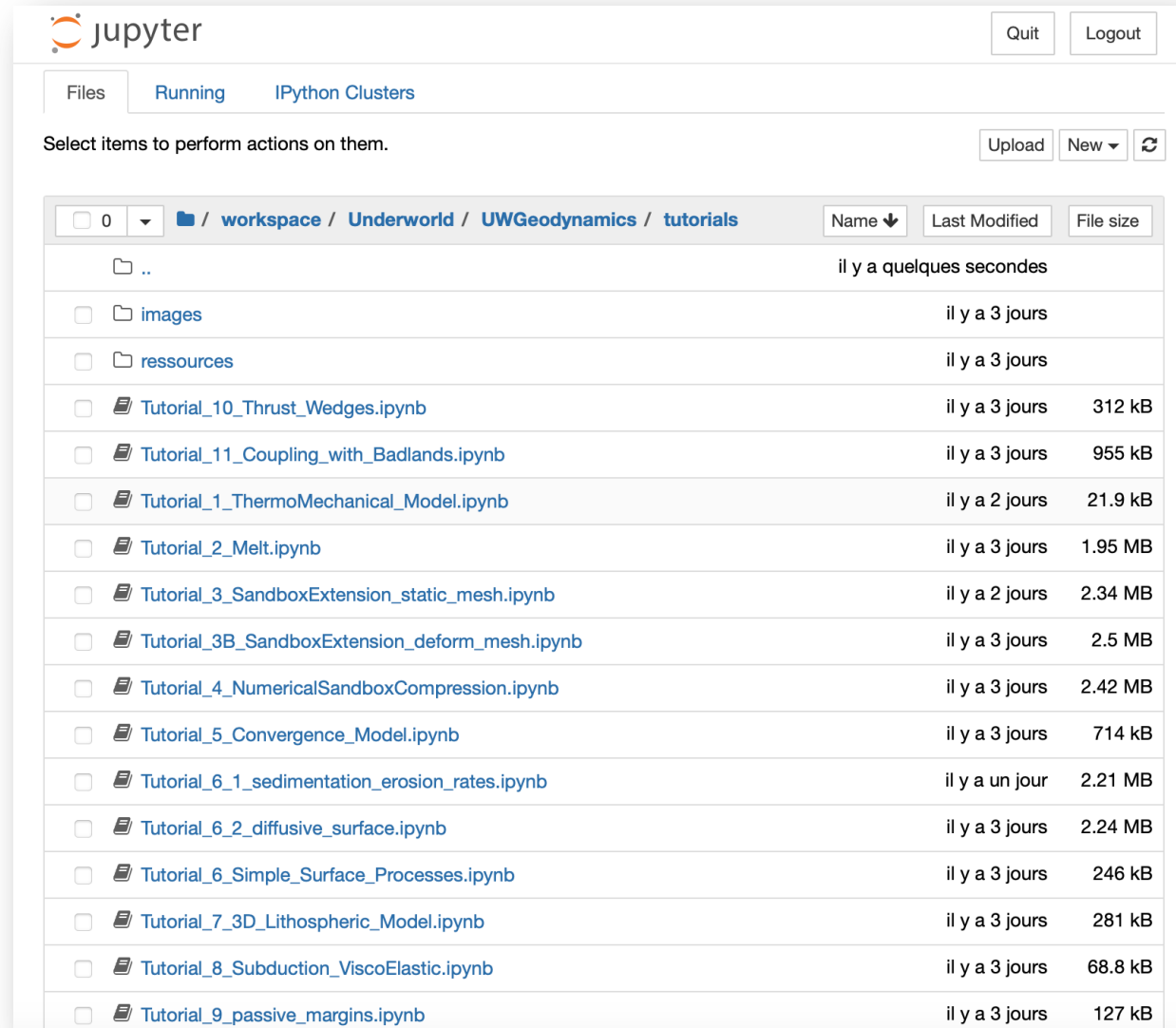
What causes the general behaviour of a system?



(b)

UW2: Let's explore together some models

In your browser, navigate to </workspace/Underworld/UWGeodynamics/tutorials>



The screenshot shows the JupyterLab interface. At the top, there is a 'jupyter' logo and 'Quit' and 'Logout' buttons. Below that, there are tabs for 'Files', 'Running', and 'IPython Clusters'. A message says 'Select items to perform actions on them.' with 'Upload', 'New', and a refresh icon. The main area is a file browser for the path '/ workspace / Underworld / UWGeodynamics / tutorials'. It shows a list of files and folders with columns for Name, Last Modified, and File size.

<input type="checkbox"/> 0	Name	Last Modified	File size
	..	il y a quelques secondes	
<input type="checkbox"/>	images	il y a 3 jours	
<input type="checkbox"/>	ressources	il y a 3 jours	
<input type="checkbox"/>	Tutorial_10_Thrust_Wedges.ipynb	il y a 3 jours	312 kB
<input type="checkbox"/>	Tutorial_11_Coupling_with_Badlands.ipynb	il y a 3 jours	955 kB
<input type="checkbox"/>	Tutorial_1_ThermoMechanical_Model.ipynb	il y a 2 jours	21.9 kB
<input type="checkbox"/>	Tutorial_2_Melt.ipynb	il y a 3 jours	1.95 MB
<input type="checkbox"/>	Tutorial_3_SandboxExtension_static_mesh.ipynb	il y a 2 jours	2.34 MB
<input type="checkbox"/>	Tutorial_3B_SandboxExtension_deform_mesh.ipynb	il y a 3 jours	2.5 MB
<input type="checkbox"/>	Tutorial_4_NumericalSandboxCompression.ipynb	il y a 3 jours	2.42 MB
<input type="checkbox"/>	Tutorial_5_Convergence_Model.ipynb	il y a 3 jours	714 kB
<input type="checkbox"/>	Tutorial_6_1_sedimentation_erosion_rates.ipynb	il y a un jour	2.21 MB
<input type="checkbox"/>	Tutorial_6_2_diffusive_surface.ipynb	il y a 3 jours	2.24 MB
<input type="checkbox"/>	Tutorial_6_Simple_Surface_Processes.ipynb	il y a 3 jours	246 kB
<input type="checkbox"/>	Tutorial_7_3D_Lithospheric_Model.ipynb	il y a 3 jours	281 kB
<input type="checkbox"/>	Tutorial_8_Subduction_ViscoElastic.ipynb	il y a 3 jours	68.8 kB
<input type="checkbox"/>	Tutorial_9_passive_margins.ipynb	il y a 3 jours	127 kB

UW2 Model architecture

